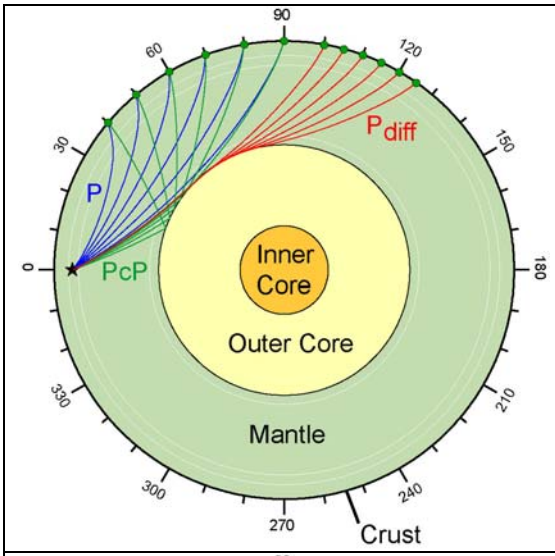
**Guide to Seismic Phases**

The change of seismic velocities within Earth, as well as the possibility of conversions between compressional (P) waves and shear (S) waves, results in many possible wave paths. Each path produces a separate seismic phase on seismograms. Seismic phases are described with one or more letters, each of which describes a part of the wave path. Upper case letters denote travel through a part of the earth (e.g. P or S), and lower case letters denote reflections from boundaries. A complete, standardized nomenclature for seismic wave paths is available at the web site: http://www.isc.ac.uk/Documents/IASPEI/sspl.html. This information has also been published [Storchak, D.A., J. Schweitzer, P. Bormann (2003), "The IASPEI Standard Seismic Phase List", Seismol. Res. Lett. 74, 6, 761-772], and a pdf file of this publication is available from the same web site.

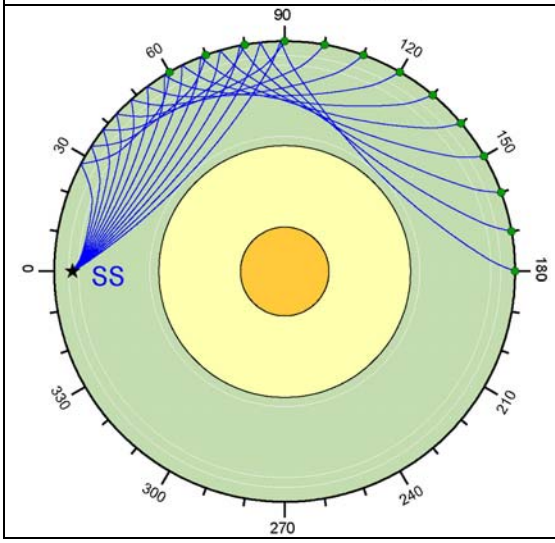
In the verification context, wave propagation in Earth is divided into *teleseismic* (distances greater than 2000 kilometers) paths and *regional* (distances less than 2000 kilometers) paths.

**Teleseismic Phases**

In these plots, the seismic event is at the left, and seismic ray paths are shown to possible stations at several angular distances from the event.




| | |
|---|---|
| **P** | A primary (compressional) wave that follows a simple path from event source to the station. |
| **PcP** | A P wave that goes downward through the mantle (the first "P"), is reflected from the top of the outer core ("c") and goes upward through the mantle to the station (second "P"). |
| **$P_{diff}$** | A P wave that has been bent (diffracted) around the outer core boundary and arrives at a station in the ray "shadow" of the outer core. |
| **S** | A secondary (shear) wave that follows a path similar to the P wave (not shown). |




| | |
|---|---|
| **SS** | A shear wave that has traveled through the mantle ("S"), undergone one reflection from the underside of Earth's surface and traveled again through the mantle (second "S"). Unlike with most other reflected waves, there is no separate letter to denote the reflection at the surface; it is implicit. |
| **PP** | A compressional wave that follows paths similar to those of SS (not shown). |

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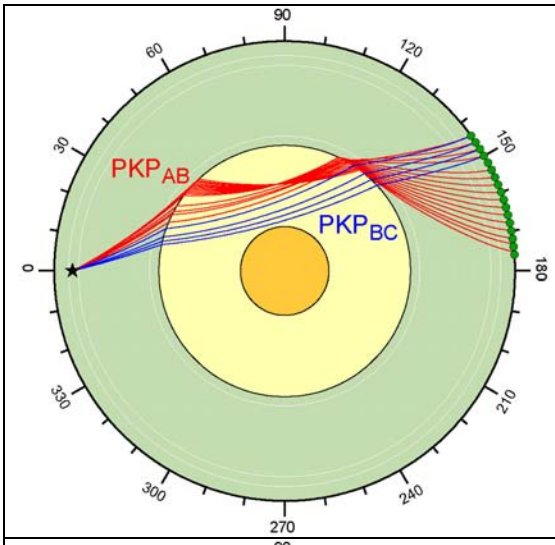
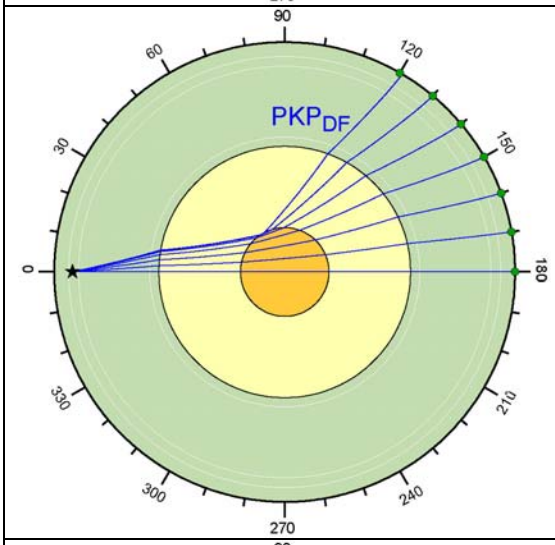
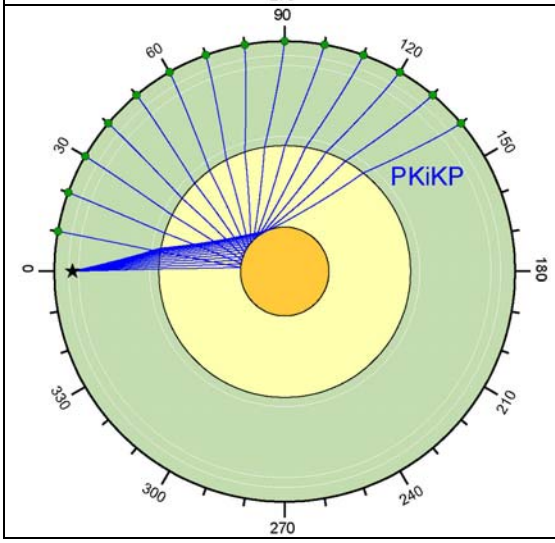
|---|---|---|
|  | **PKP** | A P wave that has traveled through the mantle ("P"), been transmitted across the mantle-outer core boundary and traveled through the outer core ("K"), transmitted back across the outer core-mantle boundary and traveled as a P wave to the station ("P"). Because of the large difference between the P wave velocity in the mantle and the outer core, this wave is bent (refracted) strongly at the boundary. Seismic waves can follow slightly different paths (labeled $PKP_{AB}$, $PKP_{BC}$) and still arrive at about the same time. |
|  | **PKIKP** | A P wave that has traveled through the mantle ("P"), been transmitted across the mantle-outer core boundary ("K"), crossed the outer-core inner-core boundary and traveled through the inner core as a P wave ("I"), then followed a similar path in reverse to get from the inner core to the station (the second "KP"). An alternate name for this phase is $PKP_{DF}$ (shown in the path illustration). |
|  | **PKiKP** | This phase has followed a series of paths similar to the PKIKP phase, except it was reflected off the top of the inner core-outer core boundary (this is the "i" part of the path), rather than being transmitted through the inner core. |

Figures courtesy of Ed Garnero, Arizona State University (http://garnero.asu.edu/research_images/index.html)

**Depth Phases**

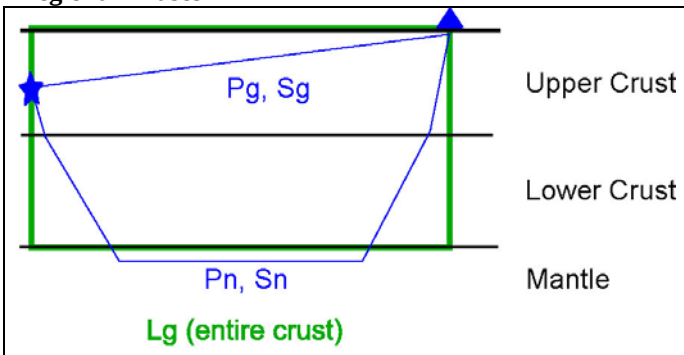
A number of "depth" phases are referred to in the proceedings. The paths of these phases are nearly the same as P waves. The depth phases all result from a reflection from the Earth's surface near the epicenter of the event. The time delay between the P wave and the depth phase is proportional to the depth of the event (hence the term "depth" phase).

**pP** A P wave that started out upward from the source ("p"), reflected off the Earth's surface, and traveled to the station as a P wave ("P").

**sP** An S wave that started out upward from the source ("s"), reflected off the earth's surface and also converted to a P wave, which then traveled to the station as a P wave ("P").

**pwP** Similar to the pP phase. A P wave that started out upward from the source ("p"), reflected off the ocean surface ("w" - water) and traveled to the station as a P wave ("P").

**Regional Phases**




A highly simplified representation of the crust of Earth, which is seldom so simple and flat. Changes of crustal thickness and velocities can disrupt crustal phases, notably Lg.

**Pg (Sg)** At short event-station distances, an upgoing P (S) wave from a source in the upper crust (depicted here) or a P (S) wave bottoming in the upper crust. At larger distances the Pg phase includes arrivals resulting from multiple P-wave reverberations within the entire crust that propagate at a group velocity around 5.8 km/s.

**Pn (Sn)** A P (S) wave bottoming in the uppermost mantle or an upgoing P wave from a source in the uppermost mantle

**Lg** A wave group observed at larger regional distances and caused by superposition of multiple S-wave reverberations and S to P and/or P to S conversions inside the whole crust. The maximum energy travels with a group velocity around 3.5 km/s