schemes, such as finite-difference ray tracing (e.g., Vidale, 1988) and graph theory (e.g., Moser, 1991) have often proven more stable. These methods also have the convenience of requiring model slowness values only at fixed grid points (usually evenly spaced) within the model.

4.9 Ray nomenclature

The different layers in the Earth (e.g., crust, mantle, outer core, and inner core), combined with the two different body-wave types (P, S), result in a large number of possible ray geometries, termed *seismic phases*. The following naming scheme has achieved general acceptance in seismology:

4.9.1 Crustal phases

Earth's crust is typically about 6 km thick under the oceans and 30 to 50 km thick beneath the continents. Seismic velocities increase sharply at the Moho discontinuity between the crust and upper mantle. A P wave turning within the crust is called Pg, whereas a ray turning in or reflecting off the Moho is called PmP (Fig. 4.14). The m in PmP denotes a reflection off the Moho and presumes that the Moho is a first-order discontinuity. However, the Moho might also be simply a strong velocity gradient, which causes a triplication that mimics the more simple case of a reflection. Finally, Pn is a ray traveling in the uppermost mantle below the Moho. The *crossover point* is where the first arrivals change abruptly from Pg to Pn. The crossover point is a strong function of crustal thickness and occurs at about $X = 30$ km for oceanic crust and at about $X = 150$ km for continental crust. There are, of course, similar names for the S-wave phases (SmS, Sn, etc.) and converted phases such as SmP.

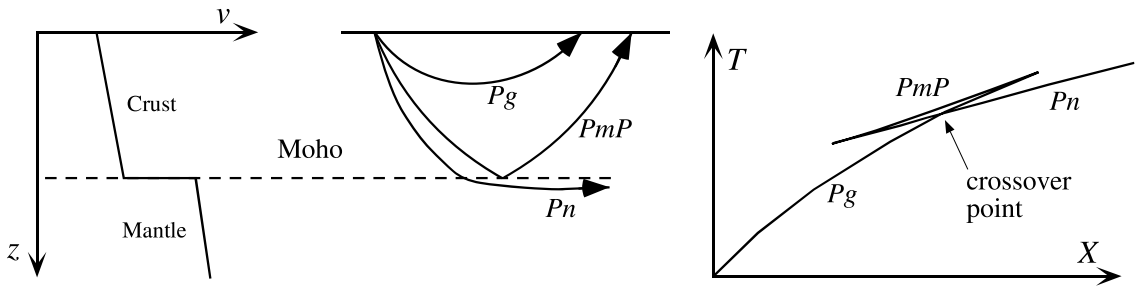

Figure 4.14 Ray geometries and names for crustal *P* phases. The sharp velocity increase at the Moho causes a triplication in the travel time curve.

4.9.2 Whole Earth phases

Here the main layers are the mantle, the fluid outer core, and the solid inner core. *P*- and *S*-wave legs in the mantle and core are labeled as follows:

P – *P* wave in the mantle
K – *P* wave in the outer core
I – *P* wave in the inner core
S – *S* wave in the mantle
J – *S* wave in the inner core
c – reflection off the core–mantle boundary (CMB)
i – reflection off the inner-core boundary (ICB)

For *P* and *S* waves in the whole earth, the above abbreviations apply and stand for successive segments of the ray path from source to receiver. Some examples of these ray paths and their names are shown in Figure 4.15. Notice that surface multiple

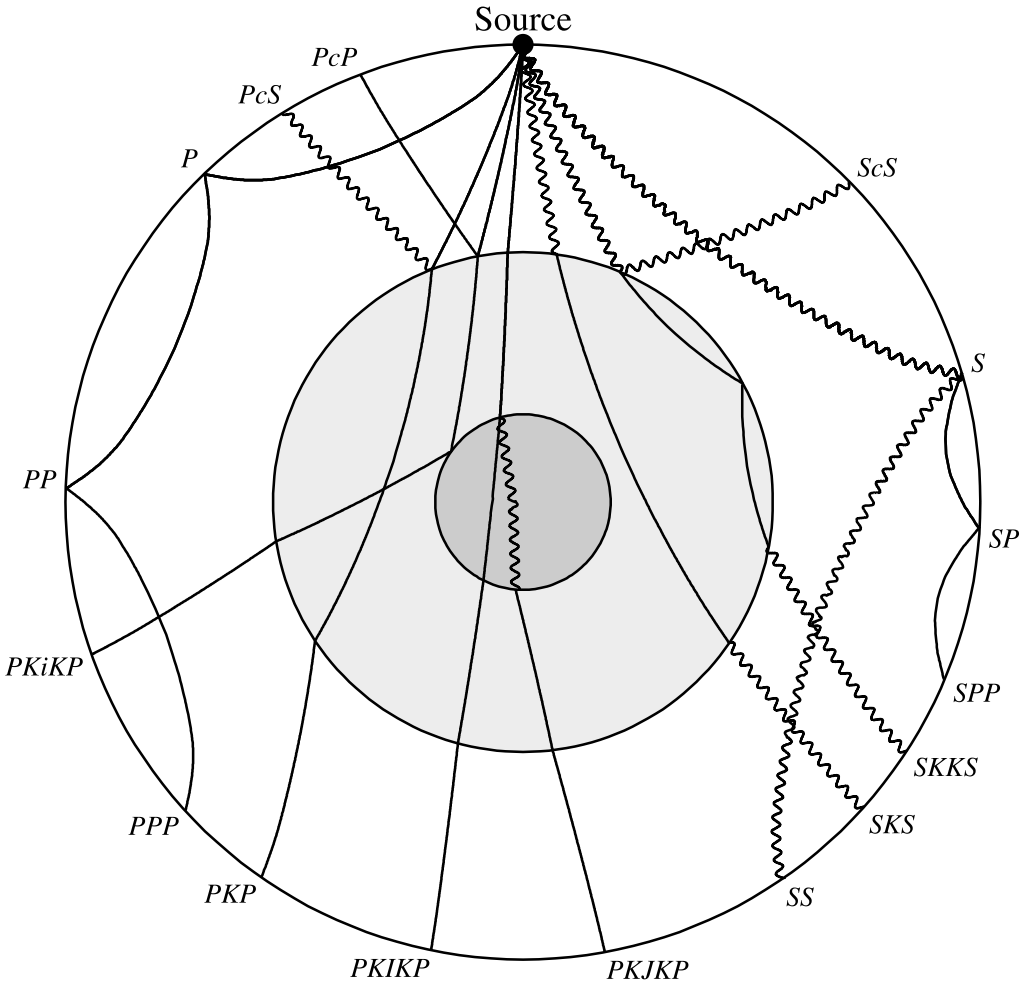

Figure 4.15 Global seismic ray paths and phase names, computed for the PREM velocity model. *P* waves are shown as solid lines, *S* waves as wiggly lines. The different shades indicate the inner core, the outer core, and the mantle.