Low velocity zone of upper mantle and its effect on PdSwr phase related to 670 km discontinuity

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Abstract

This paper studied some properties of PdSwr phase related to 670 km discontinuities in detail, and theoretically processed a preliminary analysis to this phase. We discussed the relationships between the incident angle \( i_h \) of PdSwr phase with its path, epicentral distance, travel-time and relative amplitude due to low velocity zone (LVZ) of upper mantle, and preliminarily pointed out the main characters of PdSwr phase recorded in seismogram. The PdSwr phase is concentrated in range of 13.5°-96.5°. When epicentral distance is greater than 33°, the start point of PdSwr phase is relatively well distinguishable and could thus be determined more easily. When the epicentral distance is between 13.5° to 33°, the triplication of PdSwr’s travel-time curve could be slightly distinguished due to the low velocity zone and 220 km seismic velocity discontinuity of upper mantle. The relevant observed PdSwr phase should be in a more complex pattern and it should be more difficult to determine its start point.

Key words: low velocity zone discontinuity incident angle of seismic ray travel-time epicentral distance

Introduction

The seismic wave velocity models of the Earth interior, from a simple three layers model only including mantle, outer and inner core in 1930s, to PREM model in 1980s (Dziewonski, Anderson, 1981), further to iasp91 model in 1990s (Kennett, Engdahl, 1991), have made mighty advances along with the progresses of modern seismological observed techniques and vice versa. It has been substantiated that there exists a transition zone of seismic wave among 50-220 km and three typical seismic wave velocity discontinuities with depths of 220, 400 and 670 km of upper mantle. There might even be a seismic wave velocity discontinuity of depth 920 km based on the recent study of Kawakatsu and Niu (1994).

When seismic ray reflects/transforms or refracts/transforms only one time through a specific discontinuity, there are 20 related seismic phases, where 12 phases are not through earth’s core while the other 8 are through the core (Wei, et al, 1993). This paper only studied the characters of PdSwr phase related to 670 km discontinuity, and especially discussed the relationships of PdSwr ray’s epicentral distance (\( \Delta \)) versus its incident angle (\( i_h \)) and its relative amplitude (\( A_r \)), respectively. PdSwr is a phase that the ray starts off from the focus downwards to the low velocity zone (if a shallow focal earthquake) and 670 km discontinuity of upper mantle as P wave, turns over upwards before contacting the core-mantle boundary, and then transforms into S wave after crossing the 670 km discontinuity once again (Figure 1). Based on the travel-time of PdSwr phase,
there are some properties as follows: ① PdSwr can be generally recorded in a relatively wide range of epicentral distance about from 13.5° to 96.5°; ② For a shallow focal earthquake, PdSwr is located between sP and PP phases in range of 30°–96.5°, or between sP and S phases in range of 13.5°–30° (Wei, et al, 1993; Institute of Geophysics, State Seismological Bureau, 1980a, b).

Studying the subtle seismic wave velocity structure of upper mantle, especial properties of the discontinuities in range of 400–670 km, is crucial for us to understand the mantle evolution. It is also significant for our further solving a series of traditional geodynamical problems which remain unclear up to now, for example, mantle flow modes and plate driving mechanics and so on (Hager, Richards, 1989; King, Masters, 1992; Forte, et al, 1995; Wen, Anderson, 1995). Applications of modern digital seismological techniques, which include the employment of global seismological network and local array records, and the corresponding signal processing techniques, have made our work easier to distinguish and analyze the weak seismic phases related to discontinuities from seismogram than before. By using P phase or reflective transform phases, some researchers studied local subtle structure of upper mantle beneath different regions (Walck, 1984, 1985; Tajima, Grand, 1995). In the meanwhile, refractive transform PdSwr is also an important seismic phase used in studying the structure of upper mantle with discontinuities. Based on studies of 670 km discontinuity in different regions of continental area, Kind, et al (1988) and Stammler, Kind (1991) pointed out that it is possible to study the characters and properties of upper mantle discontinuities by using PdSwr phase. They indicated that existed a global range of distinguishable PdSwr phase connected with an upper mantle discontinuity, which is in 660 km depth in general. By using some long period seismograms to Northern Tuotuo river earthquake occurred on November 5, 1988, in Qinghai Province, Zhou, et al (1994) studied the properties of upper mantle 670 km discontinuity beneath the focal area, and discussed the possible lateral seismic wave velocity differences of this region. Wang, et al (1994) studied the polarization processing and identification technique to PdSwr phase, and got a primary depth distribution of upper mantle 670 km discontinuity beneath the Chinese mainland by analyzing long period seismograms of CDSN stations. Chen and Zang (1998) analyzed the depth distribution of discontinuities beneath the northeastern part of China by using CDSN network data. Their study demonstrated that there are several seismic wave velocity discontinuities covered range of 150–1 100 km depths. Shen, et al (1998) studied the properties of so called 410–660 km transition zone beneath southeastern Pacific Rift region by using PdSwr related to 660 km discontinuity.

On the other hand, low velocity zone of upper mantle with depths from 50 km to 220 km also finitely influence the related phases, for example, the recent studies to Eastern Pacific Rift region (The MELT Seismic Team, 1998; Toomey, et al, 1998; Webb, Forsyth, 1998). The existence of low velocity zone and discontinuity of rapid velocity increase can theoretically lead to shadow zone in some epicentral distances and triplication in other epicentral distances of travel-time curve of some related phases, respectively. That P phase rapidly decreases in velocity with depth and S phase fades away in outer core, and that P and S phases largely increase in velocity with depth through outer-inner core boundary, are the typical examples (Dziewonski, Anderson, 1981). Some