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PKP Waveform Complexity and Its Implications to Fine Structure Near the Edge of African Large Low Shear Velocity Province

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P wave traveling through the Earth's core typically includes three distinct phases, PKPdf (or PKIKP), PKPbc and PKPab and these waves have been frequently analyzed to study the structure of the outer-core and inner-core. It is well known that PKPab waveform suffers a 90-degree phase shift when encountering an internal acoustics in the outer-core and it is theoretically equivalent to Hilbert-transformed PKPbc (or PKPdf) waveform. Here, we report a dataset from an intermediate-depth earthquake in Vanuatu Islands recorded by a PASSCAL broadband array in Cameroon, West Africa. Two anomalous features stand out in this record section. First, in the period of a few seconds and longer, most PKPab waveforms recorded by this array are anomalous in a way that they do not display a 90-degree phase shift that is observed in other stations in Europe. Secondly, in the high frequency band of 0.5 Hz to 2 Hz, two large arrivals separated by about 3.4 seconds are observed in the time window of PKPab phase and they are often absent in the time window of PKPdf and PKPbc phases. In addition, the second arrival seems suffer some degree of phase shift relative to the first arrival.

We examine several other record sections from nearby events in Tonga and they do not show such an anomalous feature, suggesting that receiver structures are probably not the cause of this observation. Note that the take-off angle of PKPab is typically 9-12 degrees shallower than that of PKPdf and PKPbc and it is possible that near-source scattering from the slab may account for such an anomalous feature. We make Hilbert transform of P waveforms recorded at shorter range of less than 90 degrees and compare them with these anomalous PKPab waveforms. However, these Hilbert-transformed P wave show a clear 90-degree phase shift relative to PKPdf and PKPbc and they are different from PKPab waveforms, despite a difference in take-off angles of less than 5 degrees in some cases.

It appears that near-source scatterings and receiver-side structure do not play a predominant role in generating these anomalous PKPab waveforms. We then look into structural anomaly near the core-mantle-boundary (CMB) since PKPab grazes the CMB at a very shallow angle and it can effectively interact with it and possibly produce anomalous PKPab waveforms. We first explore 1-D model space by introducing velocity anomaly directly above the CMB, with a velocity perturbation up to a few tens of percents in S wave velocity and P wave velocity. We calculate synthetics up to 2 Hz by Direct Solution Method (DSM) and Reflectivity Method to examine waveform anomaly at long period band (0.01-0.2 Hz) as well as short-period band (0.5-2 Hz). Our preliminary result indicates that the model with a thin ($\sim$ 15 km) ultra-low velocity zone (ULVZ, 30% reduction in P wave and S wave velocity) is capable of reproducing characteristics of these anomalous PKPab waveforms at both frequency bands. The pierce points of PKPab in the source side at CMB are near the southeast Indian Ocean where S wave velocity is only slightly faster than PREM. On the other hand, the pierce points in the receiver side are at the eastern edge of the African Large Low Shear Velocity Province (LLSVP). One interesting feature of our ULVZ model is that dlnVs/dlnVp is about 1, which is different from most ULVZ models where dlnVs/dlnVp is about 3.