Seismic Velocity Contrast Along the Longitudinal Valley Fault System, Taiwan, from Analysis of Fault Zone Head Waves and Direct P Arrivals

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Fault zone head waves (FZHWs) generated by bimaterial interfaces are the first arriving seismic phases at near-fault stations on the slower side of the fault. Since FZHWs spend almost their entire path along the fault interface, imaging methods based on these phases can provide high-resolution information on fault structure at seismogenic depths. In Eastern Taiwan, many past catastrophic earthquakes highlight the need for an improved understanding of fault characteristics and mechanical properties in this tectonically active environment. Here we use FZHWs to examine the northern segment of the Longitudinal Valley (LV) fault system, a suture zone between the Eurasian Plate and the Philippine Sea plate. We focus on 44 stations within a 70 km by 28 km area located along the northern segment of the LV fault system and ~8800 small-to-moderate earthquake seismograms recorded between 2012 and 2018 by those stations. We apply a set of algorithms developed by Ross and Ben-Zion to automatically detect and pick direct P waves, S waves and potential head waves contained in the seismograms. We augment the detection using finite-difference simulations to study the effect of varying source mechanisms on the first motion polarity characteristics of the P wave and FZHW. The results indicate that head waves will be generated not only by a clean strike-slip fault but by a wider range of focal mechanisms. We discuss 414 robustly detected head waves excited by 204 events that are located within a thin volume along the west-dipping Central Range fault, which now suggests—for the first time—the existence of a consistent velocity contrast across that fault segment. We apply particle motion, polarization, and moveout analyses to confirm the robustness of our FZHW phase picks obtained with the automatic method. Most particle motion and polarization results show that the azimuths calculated from windows containing direct P waves do not consistently point to the epicentres. This variability in horizontal particle motion is likely associated with the complex structure beneath the receivers and changes in topography. To the first order, the moveout pattern of the P wave to FZHW time difference is constant. This indicates a shallow bimaterial interface along the fault that affects the wavefield near or below the stations. We fit the moveout and constant arrivals with two models to the differential P and head wave arrival times to explore possible local variations of the generally constant trend. The Akaike Information Criterion applied to the constant and the sloping moveout pattern suggests spatially complex significant results that
together with the depth distribution of the involved events indicate a deeper-reaching bimaterial interface. For these configurations, the obtained average velocity contrast ranges from 0.75 to ~3 per cent.