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Anomalies of rupture velocity in deep earthquakes

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Explaining rupture mechanics and seismicity of deep earthquake is a long-standing challenge in earth science. Previous researchers had estimated seismic rupture process of deep earthquake on the basis of the seismic wavefrom modeling. From previous source studies, however, it had been difficult to find clear characteristic in rupture process of deep earthquake, since seismic source models for same deep earthquake are often quite different from one another. To estimate stable and detailed rupture model of deep large earthquakes, we applied the back projection method to tele-seismic body waveforms (P-wave) recorded Global Seismograph Network (GSN) and Federation of Digital Broad-Band Seismograph (FDSN). Using this method, we can obtain an image of the seismic source process from the observed data without a priori constraints or discarding parameters. We further applied 4th-root stacking technique which significantly improved resolution of rupture image compared to standard linear stacking. By imaging the seismic rupture process for a set of recent deep earthquakes using the back projection of teleseismic P-waves, we found that the rupture velocities are less than 60% of the shear wave velocity except in the depth range of 530 to 610 km. In this exceptional depth range, about eighty percent of earthquakes have fast rupture velocity ($Vr > 0.6Vs$) and seismicity reaches local maximum. We propose that large fracture surface energy (Gc) values for deep earthquakes generally prevent the acceleration of dynamic rupture propagation and generation of earthquakes between 300 and 700 km depth, whereas small Gc value in the exceptional depth range promote dynamic rupture propagation and explain the seismicity peak near 600 km.

Keywords: deep earthquake, back projection method, rupture process, rupture velocity