Source Rupture Processes of the 2016 Kumamoto Earthquake Sequence from Strong Motion Data

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The 2016 Kumamoto earthquake sequence started with an M_J 6.5 foreshock at 21:26 on 14 April, 2016, and another M_J 7.3 mainshock occurred at 01:25 on 16 April, just 28 hours after the foreshock. We estimated the source rupture processes of the foreshock and the mainshock of this earthquake sequence by the multiple time window linear waveform inversion technique using strong motion data (e.g., Hartzell and Heaton, 1983; Sekiguchi et al., 2000).

For the analysis of the foreshock, we assumed a nearly vertical planar fault plane (strike 212, dip 89, length 14 km, and width 13 km) along the northern part of the Hinagu fault considering the aftershock distribution and the moment tensor solution by F-net project of NIED. We analyzed velocity waveforms in 0.05-1 Hz recorded at 13 strong motion stations of K-NET, KiK-net, and F-net. The obtained source model has a large slip area near the rupture starting point at a depth of 11.4 km. Another large slip area is found close to the northern edge of the fault at a depth of approximately 5 km. That is, the rupture of the foreshock mainly propagated northeastward with almost pure right-lateral strike-slip, and it would be a reason why severely strong ground motion was observed in Mashiki town, which is located northeast of the epicenter. The total seismic moment is 2.04×10^{18} Nm (Mw6.1), and the average and maximum slip amount is 0.36 m and 1.2 m, respectively. The best estimate of the first time-window front triggering velocity is 2.2 km/s.

For the mainshock, northwestward dipping fault plane along the Futagawa fault is expected by the spatial distribution of the aftershocks and the coseismic crustal deformation analyzed by the Geospatial Information Authority of Japan. The aftershocks occurring along the Hinagu fault also appear to align on a northwestward dipping fault plane. The several emergency field survey teams dispatched from the Geological Survey of Japan, Tohoku University, and other institutes reported the surface breaks along both of Futagawa and Hinagu fault zones. Thus, we assumed a source model consisting of two planar fault planes; one along the northern part of the Hinagu fault (strike 205, dip 72, length 14 km, and width 18 km), and the other along the Futagawa fault (strike 235, dip 65, length 28 km, and width 18 km). We analyzed velocity waveforms in 0.05-0.5 Hz recorded at 15 strong motion stations of K-NET, KiK-net, F-net, and JMA. The slip on the Futagawa fault initiated from the deep portion of the fault, and propagated northeastward and to the ground surface. The largest slip is observed at depth approximately 8-10 km, and the slip amount of the shallowest subfault approximately ranges from 1 to 3 m. The subfaults in the shallow part close to the northern end of the Hinagu fault also has relatively large slips, and these slips corresponds to the emergence of the surface breaks. By comparing the temporal slip progression on the fault estimated by this study with the observed displacement waveforms without filter at two strong motion stations nearby the surface fault, which are not used in the inversion analysis, we could confirm that the large fault parallel displacements at these two stations coincide with the rupture of the fault in front of the stations. The total seismic moment is 4.67×10^{19} Nm (Mw7.0), and the average and maximum slip amount is 1.9 m and 5.3 m, respectively. The best estimate of the first time-window front triggering velocity is 2.4 km/s.

From above analysis, we conclude that the rupture of the 2016 Kumamoto mainshock continuously propagated from the northern part of the Hinagu fault to the Futagawa fault. This earthquake scenario is quite similar to the old long-term evaluation of the Futagawa-Hinagu fault system published in May 2002 by the Headquarter of Earthquake Research Promotion.

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