Spatial relation between fault motions and density structures at the terminus of fault rupture for the 2016 Kumamoto earthquake

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Introduction

The purpose of this study is to clarify what kind of characteristic crustal structure exists at and around the terminus of fault rupture, and is to discuss what possibly controls fault ruptures in the final stage. For the purpose, we here explored the spatial relationship between the SAR-derived fault motions and the crustal structure inferred by gravity. The target seismic event is the 2016 Kumamoto earthquake in Japan.

Data analysis

First, we conducted split-bandwidth interferometry for both range and azimuth components in addition to conventional InSAR analyses using ALOS-2 SAR data, and obtained the crustal deformation over the source region including nearby the faults. We further estimated the full 3D displacement field by a least squares method, using the derived displacements with multiple view angles. Next we estimated the fault parameters for nine faults in total, including the Hinagu and the Futagawa faults. We estimated each fault parameter using the Simulated Annealing (SA) method, and then we estimated the slip distribution on each fault plane which is estimated by the SA analysis.

Next, we inverted the campaign data and pre-existing gravity data to estimate the density contrast structure under the ground. First, the complete Bouguer gravity anomaly reflecting the internal heterogeneity of the Earth was obtained by removing the influence of gravity not caused by the Earth's mass structure and applying Bouguer correction and topographic correction. The 3D density contrast was estimated by the weighted least squares method, using the gravity of parallelepiped masses as the response function. In the analysis, the density given as the initial value was calculated in various patterns to obtain a reliable solution while considering the dependence on the initial value.

Result

The mapped crustal deformation shows that the displacement boundary, which is presumed to be caused by fault movements, extends on the eastern extension of the Futagawa fault and bifurcates mainly in two directions at the western margin of the Aso caldera. One is a right lateral displacement on the eastern extension of the Futagawa fault accompanied with subsidence on the southern side, and the other is a left lateral displacement with subsidence on the northern side. We can find that localized displacement boundaries of several kilometers in length with right lateral motion are also observed. These boundaries are linearly distributed, which strongly suggests that they are caused by fault movements. The modeling analysis shows that the fault movement on the eastern extension of the Futagawa fault is a right lateral slip on a south-dipping fault plane, and the other fault has a left lateral slip on a north-dipping fault plane. Both of them have dip angles of about 40-50 degrees. The faults corresponding to the local deformations show right lateral slip on a nearly vertical fault plane. The fault system composed of these faults suggests the structure of the so-called flower structure.

The estimated density contrast structure shows that a wedge-shaped low-density body exists at the shallow part in the western part of Aso caldera. The striking point is that the bifurcated main faults are located along the side of the low-density body, possibly suggesting that the ruptures propagated along some physical boundary featured by the anomalous density structure. Further, the rupture terminus for the local faults almost overlaps the low-density body, maybe suggesting that there exists some ductile material that terminates the brittle ruptures.

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