Research on relationship between fault rupture propagation and crustal structure of volcano area: case study of the 2016 Kumamoto Earthquake

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[Preface]

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 crustal deformation and the crustal structure inferred by gravity. The target seismic event is the 2016 Kumamoto earthquake which occurred in the proximity of the Aso volcano area.

[Data and Method]

First, we conducted InSAR analysis using ALOS-2 SAR satellite data to obtain the crustal deformation over the source region including nearby the faults. In addition to standard InSAR, we applied a split-bandwidth interferometry (SBI) method to range and azimuth components. We successfully mapped spatially detailed displacements not only in far field but also in near field where a standard InSAR cannot measure displacements due to low coherence. We finally estimated the full 3D displacement field by a least squares method, using the derived displacements with multiple view angles. We further estimated the fault parameters for nine faults in total, including the Hinagu and the Futagawa faults which are the main source faults. We first 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 pre-existing and campaign gravity data to estimate the density contrast structure. 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.

[Results]

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.

The estimated density contrast structure shows that a low-density body exists at the shallow part in the western part of the Aso caldera. The striking point is that the fault motions extending into the Aso caldera terminate when contacting with the low-density body, possibly suggesting that some physical condition featured by the anomalous density structure hampers the rupture propagations. Our results might demonstrate that plastic properties in the hydrothermal environment acts as a barrier to rupture propagation and prevents from proceeding the brittle ruptures.

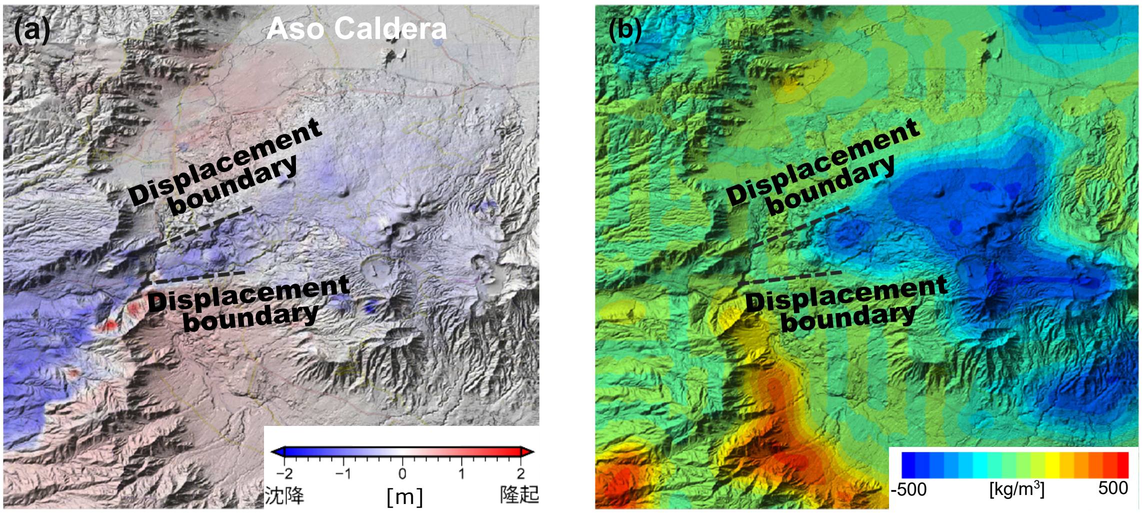

Fig. 1 (a) SAR-estimated vertical displacement map in the Aso caldera. (b) Gravity-estimated density contrast structure at 1.5 km depth.

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