Effect of complex fault systems and volcanic areas on the 2016 Kumamoto-Oita earthquake sequence

*Takahiko Uchide[1], Haruo Horikawa[1], Misato Nakai[1], Reiken Matsushita[1], Norio Shigematsu[1], Ryosuke Ando[2,1], Kazutoshi Imanishi[1]

1.Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), 2.Demartment of Earth and Planetary Science, Graduate School of Science, the University of Tokyo

The 2016 Kumamoto-Oita earthquake sequence breaking out on the night of April 14, 2016 (all time and date in this abstract are written using local time (UTC+9)) ruptured a pair of fault systems and volcanic areas. The first large event (referred to as "event #1") was Mw 6.2 at 21:26 on April 14, followed by an Mw 6.0 event ("event #2") at 0:03 on the 15th. The largest event (Mw 7.0; "event #3") took place at 1:25 on the 16th. Not only the strong ground motion from individual events, but also the series of large and medium earthquakes for a long time brought painful experiences to residents. The seismicity became active in three separated areas: the Futagawa and Hinagu fault systems where the abovementioned three large events occurred; the northern Aso area; and the Beppu-Yufuin area. We address the following questions: (1) Why were the faults ruptured by three different large earthquakes, not by a single large earthquake at once? (2) Why did the spatial gaps of seismicity appear?

We performed a relocation of hypocenters in this seismicity using hypoDD (Waldhauser and Ellsworth, 2000). The result suggests underground complex fault geometries corresponding to the Futagawa and Hinagu fault systems, composed of the NW-dipping faults and nearly vertical faults. The hypocenter of the event #1 was on a vertical fault, while that of the event #2 was on a dipping fault. The event #3 started on another vertical fault, as indicated by the first-motion polarity mechanism, close to the intersection with the dipping fault. The irregularity of the fault geometry probably prevented the further rupture propagation and, at the same time, helped the nucleation for the next large earthquake. This resulted in the rupture by the series of three large earthquakes.

The seismicity gap (referred to as "Aso gap") between the Futagawa fault system and the northern Aso was ruptured by the event #3, as revealed by the slip inversion analysis using strong-motion data from KiK-net of NIED. It is probable that the event #3 completely ruptured the Aso gap and remained little stress to produce its aftershocks. This condition should be somehow related to the volcanic structure of Mt. Aso, although rigorous discussions require a detailed structure model and resultant fault behaviors.

At Yufuin, we found a dynamic triggering event by visual inspection of highpass-filtered seismograms from K-NET and KiK-net of NIED. The dynamic triggering events have often been found in volcanic areas (e.g., Hill et al., 1993). A simple comparison of the amplitudes of seismograms highpass-filtered at 16 Hz with those of the nearby Mw 5.1 event that occurred at 7:11 on April 16, 2016 implies that the triggered event is mid-M6. The estimated magnitude is consistent with the rupture length inferred from the InSAR image by GSI from ALOS-2 and the extent of the area where the seismicity became active after the event #3. This dynamic triggering mechanism produced the apparent gap in seismicity between Yufuin and northern Aso area.

Our careful data analyses revealed the mechanism of the curious seismic activity in the 2016

Kumamoto-Oita earthquake sequence, although a number of questions are still remained, such as the mechanism of the formation of the complex fault system, and the relationship between the Aso gap and Mt. Aso. The influence of this earthquake sequence on the volcanic activities is also of interest. These studies will help us to make better assessment of seismic and volcanic hazards.

Acknowledgement
We used the phase data from the JMA Unified Earthquake Catalog based on data from seismic stations maintained by JMA, NIED, and Kyushu University; material from NIED: seismograms from Hi-net, KiK-net, and K-NET, and the F-net Moment Tensor Catalog; and the moment tensor catalog from the Global CMT Project.

Keywords: Seismology, The 2016 Kumamoto earthquake, Dynamic triggering of earthquakes, Slip inversion analysis of earthquake, Hypocenter relocation, Mt. Aso

