A review of the seismotectonics and paleoseismic studies related to the 2016 Kumamoto earthquake and lessons for long-term earthquake forecasting

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The 16 April 2016 M_w=7.0 (M_j=7.3) Kumamoto earthquake struck the city of Kumamoto, its suburbs in central Kyushu, Japan, and brought significant damage to more than 250,000 buildings, killing 50 people. It was not sudden occurrence of a large earthquake but preceded by M_w=7.0 (M_j=6.5) earthquake ~28 hr before the mainshock. An ENE-trending ~30-km-long surface rupture emerged during the mainshock along the previously mapped Futagawa fault and northern Hinagu fault. The foreshock activity and the mainshock rupture started from the junction of the Futagawa and Hinagu faults those strikes compose of a 25˚-transpressional bend, as a key fault geometry to control rupture onset and termination as pointed out by several classic papers (e.g., King, 1986). The rupture zone extended to and stopped at the Aso Caldera, one of the active volcanos, leaving up to 1.5 m right-lateral surface slip along a previously unknown 5-km-long fault zone. Such space-time development of the seismic sequence, rupture process on subsurface faults and detailed surface slip down to several centimeters were well monitored and visualized by dense seismic networks and space geodesy (GNSS and InSAR). A combination of traditional geologic reconnaissance, seismic, and geodetic analyses enable us to understand the hidden connection between the seismogenic faulting and complex surface ruptures, including the numerous shallow aseismic triggered slip detected by InSAR images.

From the viewpoint of seismo-tectonics and paleoseismology, the 2016 Kumamoto earthquake occurred at the center of the Kyushu Island where N-S stretching has been started since 6 Ma. The subduction-related volcanism, started at ~1.5 Ma in Kyushu has been significantly promoted the rift-zone activity developing numerous EW-trending normal faults synchronous with extensive volcanism. Since 0.5 Ma, right-lateral motion along the southern margin of the rift zone is thought to have been active as the Futagawa fault which was one of about 100 major active faults intensively surveyed by the Headquarters of Earthquake Research Promotion (HERP). The HERP evaluated the Futagawa fault to have 0-0.9% chance causing its characteristic earthquake in the next 30 years based on the average recurrence interval of 8,100-26,000 yr and the elapsed time of 6,900-2,200 yr since the last event. However, post-Kumamoto surveys conducted by several research groups newly uncovered the recurrence interval of 2,000-4,000 yr and elapsed time of ~2,000 yr. Thus, one could conclude that the Futagawa fault would have been almost due before the Kumamoto earthquake.

To assess the post-Kumamoto seismic hazard, paleoseismic behavior along the unruptured portion of the Hinagu fault becomes crucial together with the continuous aftershock activity and after-slip due to stress transfer by the 2016 earthquake. Several recent excavations across the Hinagu fault revealed that the inter-event time is 2,000-3,000 yr similar to the one on the Futagawa fault but the timing of the most recent event is a little younger.

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