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GEOTECHNICAL ASPECT OF DAMAGE CAUSED BY THE 2016 KUMAMOTO EARTHQUAKE

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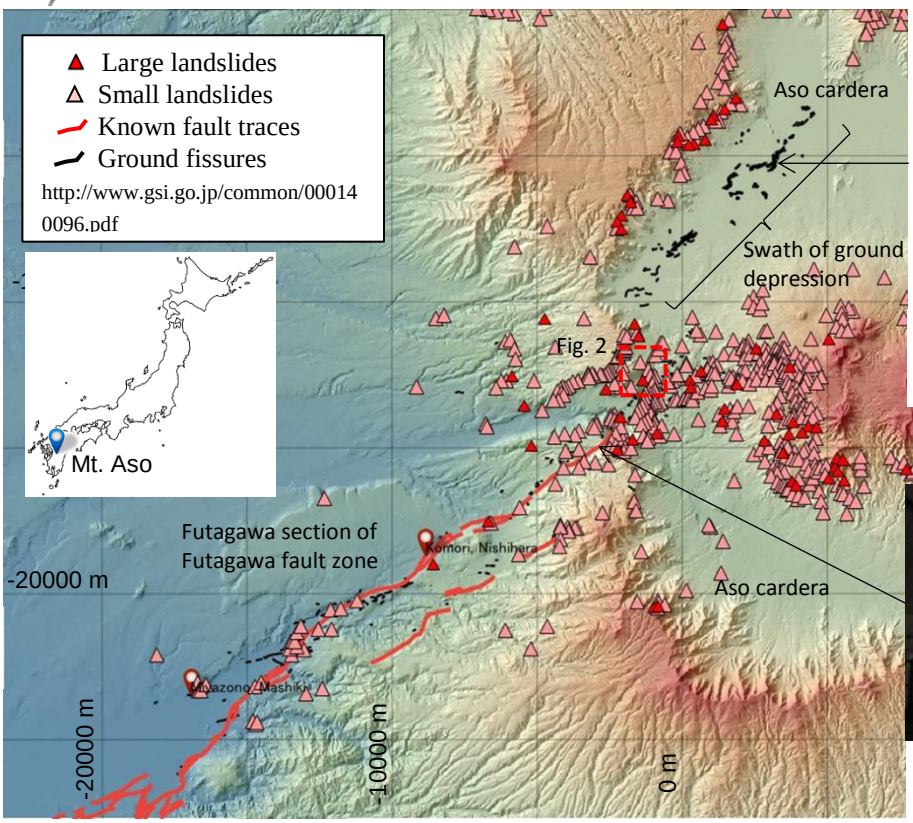
Abstract

Starting with a magnitude-6.5 foreshock on April 14, 2016, a series of major earthquakes including the magnitude-7.3 main shock on April 16 have hit the central Kumamoto area of Kyushu, Japan, causing deaths, injuries and widespread damage to various facilities. The activity of the fault, whose right-lateral offset appeared in the main shock along the previously known section of the Futagawa fault zone, caused extensive damage to roads, bridges, a tunnel and a dam. The observed features of the damage again showed that not only intense shakes but also ground deformations such as landslides, lateral spread of embankments and levees, soil liquefactions etc., which can be found within a swath along the fault trace, can be equally or often more responsible for devastations (Fig. 1). Moreover close to 500 millimeters of rain fell on some parts along the quake-hit areas on June 20 and 21, causing further extensive landslides and flooding, highlighting the difficulty to cope with earthquake-flood multi hazards.

LiDAR, Laser based altimetry, can penetrate through tree canopy, revealing detailed feature of bare earth left behind by past natural hazards, and the LiDAR image of the mountain slope along the outer rim of the Aso crater shows evidence of past landslides as well as the most recent one that has hit an important location for traffic, transmission lines and a waterway leading to a penstock (Fig. 2). Moreover cracks are seen along the exposed scar indicating future risk. Ministry of Land, Infrastructure, Transport and Tourism, MLIT, thus, has a plan to remove a greater part of the unstable soil mass remaining behind the exposed scar. However this will be a long-lasting project, and MLIT is currently taking a 2 billion JPY urgent countermeasure stabilizing the uppermost slope face of 30,000 m^2 and constructing 7m high and 300m long retaining wall near the toe of the slope using un-manned construction machinery to protect reconstruction works for national route 57 and Hohi railway line.

As long as clear evidence for past large soil deformation was there in LiDAR images, landslides/active fault maps etc., we could bring potential hazard to light and take necessary actions. However these pieces of evidence can be often buried beneath surface soil deposits. One of the seldom-seen-before phenomena in the main shock was an about 10 km-long swath of ground depression that appeared in the northwestern part of the basin of Aso caldera (Fig. 1). The damage to agricultural and forestry businesses caused by the twin quakes is very serious, reportedly reaching 23.6 billion JPY at least, which surely include those along the swath of ground depression cutting irrigation canals, water pipes, roads and others, particularly at this time of rice planting. The cause of the ground depression is not clear yet. No clear indication of sand ejecta was found, which ejecta may have canceled the soil volume that have subsided. This depression may be due to a reflection of deep-seated tectonic movements which exhibits some tensile components in the transverse direction of the swath of ground depression. By way of trial, the cracks were laid over the along-track displacements pattern analyzed by the Geospatial Information Authority of Japan using MAI (Multiple Aperture Interferometry) method. The cracks seemingly appear where large tensile strain built up. Whatever the cause was, the swath of ground depression as well as other quake and rain-induced landform changes is to be recorded in a quantitative manner, because large ground deformations can be repeated in any extreme natural events as can be seen in the past major earthquakes.

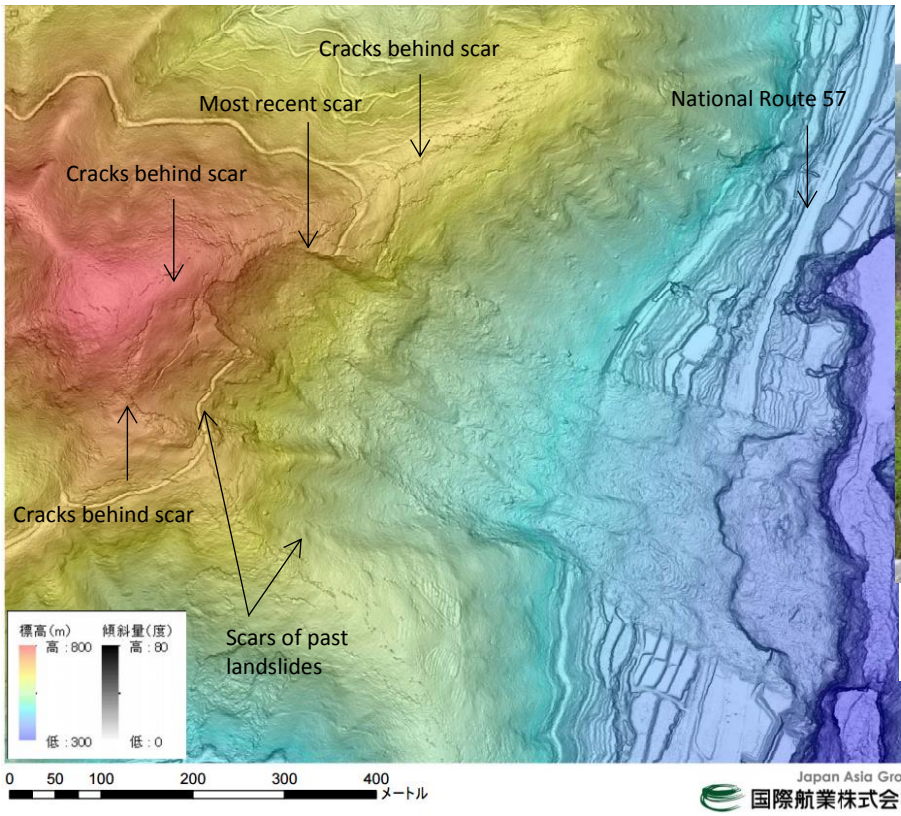
Keywords: Kumamoto, faults, large ground deformations, earthquake-flood multi hazards



House hanging a little over the northwestern offset of the ground at N32.9568º, E131.0368 (Photo by K. konagai)

Damaged Tawarayama Tunnel, N32.86012 º, E130.9681 º (Photo by K. konagai)

Fig. 1 Aerial photointerpretation of cracks and landslides that appeared on the ground surface (Coordinate reference system: JGD2000 / Japan Plane Rectangular CS II)



The Aso-ohahi (Aso large bridge) tumbled into the Kurokawa river, N32.883361 º, E130.989671 º (Photo by K. konagai)

Fig. 2 Scars of past and most recent landslides and cracks appearing behind the scars indicating future risk (LiDAR image from Kokusai Kogyo Co. Ltd., http://www.kkc.co.jp/service/bousai/csr/disaster/201604_kumamoto/index.html)