Stress fields in and around the focal area of the 2016 Kumamoto earthquake

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An M6.5 earthquake occurred in the Futagawa-Hinagu fault zone in Kumamoto Prefecture at 21:26 (JST) on 14 April, 2016. Two days after, the M 7.3 Kumamoto earthquake occurred at 1:25 on 16 April. GPS and strong motion waveform analyses revealed that the significant slip of M6.5 and M7.3 earthquake occurred on the Hinagu and Futagawa fault, respectively. Many earthquakes were induced along the fault zone even in the Oita prefecture, 100 km away the mainshock fault.
To understand the generation mechanism of the series of the 2016 Kumamoto earthquakes, it is important to investigate the state of stress and frictional strength in and around the focal area. In this study, we estimate the spatiotemporal variation of stress orientations by analyzing focal mechanism data of small earthquakes.
In order to investigate the detailed spatial variation of stress fields, we first located hypocenters of earthquakes in and around the focal area. We compiled P- and S- wave travel time data listed in the JMA unified catalogue and the Hi-net routine catalogue for 11,154 earthquakes (M> 0.5) which occurred from 1997 to 4 May 2016. We relocated hypocenters by using the Double Difference method (Waldhauser & Ellsworth, 2000). The distribution of the relocated hypocenters shows the complicated structure composed of several sharp alignments. The M7.3 earthquake seemed to occur at the bottom of the sharp alignment of the small earthquakes formed before the M7.3 earthquake.
Second, we determined focal mechanisms of small earthquakes. We applied the HASH code (Hardebeck & Shearer, 2002) to the P-wave polarity data listed in the Hi-net routine catalogue for the earthquakes which occurred during the period from 2001 to 4 May 2016, and obtained 991 high quality (rank A or B) solutions. We also added the moment tensor solutions determined by AQUA-Hi-net and F-net to the dataset. The number of the focal mechanism data obtained here is 1104.
We investigated temporal and spatial variations of stress orientations by using the focal mechanism dataset. To investigate the spatial distribution of stress orientations, we applied the slick code (Michael, 1987) to the nearest 10 ~ 15 focal mechanisms within 5 km from each location of the focal mechanisms.

1) For the period before the M6.5 earthquake, stress fields have the different feature across the Futagawa-Hinagu fault zone. In the northern side, the stress fields with s3-axis oriented to NNW-SSE and strike-slip fault stress regime is dominant. In contrast, the stress fields with s3-axis oriented to N-S and reverse fault stress regime is dominant in the southern side. The difference of the stress fields across the fault zone can be explained by the strike-slip motion along the Futagawa-Hinagu block boundary (e.g. Nishimura & Hashimoto, 2006). In the focal area of the M6.5 earthquake, the s3-axis is oriented to N-S.
2) For the period between the 14 April after M6.5 and the 16 April before M7.3 earthquakes, the s3-axis is oriented to NNW-SSE in the focal area of the M6.5 earthquake. The s3-axis rotated from N-S to NNW-SSE by 13 degrees after the M6.5 earthquake. This is significant on the basis of the 95% confidential interval.
3) For the period after the M7.3 earthquake, the s3-axis is oriented to NNW-SSE in most of locations. However, near the hypocenter of the M7.3 earthquake, the s3-axis is oriented to NW-SE, which substantially differs from the surrounding region. This NW-SE oriented s3-axis can be

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explained by the static stress change caused by the right-lateral strike-slip of the mainshock. And this suggested that the possibility of the rotation of the stress field after the M7.3 earthquake and thus we could consider that the deviatoric stress is very small in the focal area and the reduction of frictional strength may play an important role of the occurrences of the series of the earthquakes.

Keywords: stress field, frictional strength, focal mechanism, fault structure, The 2016 Kumamoto earthquake

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