How to interpret vertical-CLVD moment tensor solution at active calderas with ring faults? ―Case studies at Sierra Negra in the Galápagos Islands and Kilauea in Hawaii

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At active calderas with a ring-fault system, M_w~5 moderate earthquakes with deviatoric moment tensors dominated by a vertical compensated-linear-vector-dipole (vertical-CLVD) component are sometimes generated. Ring-faulting, dip-slips along the ring-fault system induced by pressure change of a shallow magma chamber at calderas, can cause such earthquakes with vertical-CLVD moment tensors (Shuler *et al.* 2013, JGR). However, the deviatoric moment tensor inversion using long-period teleseismic data has been known to be very unstable because at a shallow source depth M_{xz} and M_{yz} are inefficient in exciting long-period seismic waves, and therefore unresolvable; this issue makes it difficult to interpret moment tensor solutions of ring-faulting, limiting our understanding of the source properties.

We propose a method to constrain ring-fault geometry by focusing on the ratio and the polarity of the other moment tensor components that are well-resolved from long-period teleseismic data, i.e., the vertical-CLVD (CLVD) and the vertical strike-slip (SS) components. We suggest that the arc length of ring fault can be inferred from the dominancy of the CLVD component, whereas the ring-fault orientation can be constrained from the azimuth of the tension- or pressure-axis of the SS component.

We apply the method to vertical-CLVD earthquakes observed at two calderas with a ring-fault system: Sierra Negra in the Galápagos Islands and Kilauea in Hawaii. We first investigate the arc angle and orientation of the fault geometry of several ring-faulting events during volcanic activities in 2005 and 2018 at the summit caldera of Sierra Negra. The difference in the tension-axis orientation of the SS component indicates variations in the slip location along the ring-fault system. Additionally, the polarity reversal of the CLVD component between the two events in 2018 indicates that the slip direction changed before and after the eruption onset. We also apply the method to recurring M~5 seismic events during the 2018 Kilauea summit caldera collapse. We infer that the summit caldera collapses occurred with partial ring-faulting along either the northwestern or southeastern segment of the ring-fault system. Our estimations of the ring-fault geometry and kinematics at the two volcanoes are consistent with those inferred from geodetic observations and/or near-field seismic data.

These results show the usefulness of long-period teleseismic data for estimating a ring-faulting source, although parts of the source information, such as ring-fault dip angle and seismic moment, are indeterminate. By utilizing the well-resolved moment tensor components, we are able to examine remotely the structures and kinematics below active calderas with ring faults that are distributed globally. Lastly, we also discuss possible biases in the deviatoric moment tensor inversion caused by a volumetric change that potentially coincides with the ring-faulting.