Variation of coseismic fault displacements on multiple seismic cycles at a site: An example from the Kamishiro fault, Itoigawa-Shizuoka Tectonic Line active fault system, central Japan

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Predicting coseismic fault slip at a site on an active fault is crucial from the view point of fault displacement hazard assessment. The characteristic earthquake model, where an amount of coseismic slip at a point on a fault is roughly consistent through seismic cycles (Schwartz & Coppersmith, 1984), has been widely accepted and applied for hazard assessment. However, recent paleoseismic studies, high-resolution topographic data and quantitative more precise dating techniques have revealed that many faults do not repeat persistently their characteristic displacements (e.g., Zielke, 2018).To further discuss this issue, however, more case studies in particular on a dip-slip fault are required.
We estimated co-seismic slips of paleo-earthquakes at Oide site (36.7°N, 137.87°E) on the Kamishiro fault and evaluated variability in co-seismic slips through seismic cycles. The Kamishiro fault is a reverse fault which is located at the northernmost part of the Itoigawa-Shizuoka Tectonic Line active fault system in Japan. Advantages of this fault are that the co-seismic slip distribution of the most recent event, the 2014 Nagano-ken-hokubu earthquake (Mw 6.2), is precisely measured by field observation and differential LiDAR analysis, and that there is a flight of displaced terraces that record slips of recent earthquakes. Several paleoseismic studies share the evidence for the penultimate and the antepenultimate events that occurred in AD 1714 and ~1.2 ka (AD 841 or AD 762) respectively, whereas the event ages older than 1.2 ka are not well constrained. Here we mapped five displaced terraces (T1-T5, from the older) at Oide using aerial photographs taken by the US Armed Forces in the 1940s. Then, we estimated cumulative net slip of T1, T2 and T5 terraces using a tool developed by Wolfe et al. (2018) which incorporates topographic and fault properties with uncertainties and enables us to objectively estimate a plausible cumulative net slip. We made 30 topographic profiles for each terrace, and sought the mean and standard deviation of the cumulative net slip. We also constrained terrace ages based on radio carbon dating. As a result, we estimated coseismic slips of the penultimate and the antepenultimate events, 1.5±0.2 m and 2.7±0.4 m, respectively. Next, we performed a Monte Carlo simulation to estimate slips of events before the antepenultimate earthquake and then explore a possible range of CV (Coefficient of Variation) for co-seismic slips. CV is a ratio of a data set’s standard deviation to mean and used to assess variability. Low CV indicates co-seismic slips are nearly the among seismic cycles, and high CV (close to 1) means slips are variable. Because previous paleoseismic studies found one to three earthquakes occurred between T1 formation (5-2.7 ka) and 1.2 ka, we iteratively computed one to three co-seismic slips before 1.2 ka so that the simulated slip sequences can reproduce the cumulative terrace offsets. This approach enabled us to calculate CV that ranged from 0.3 to 0.5 (1 σ), which indicates that a recent sequence of co-seismic slips at Oide does not follow the characteristic earthquake model but varies in a narrow range.

Keywords: Active fault, Paleoseismology, Co-seismic slip, Monte Carlo simulation

