REPORT ON SLOW-TO-FAST EARTHQUAKES WORKSHOP AND FIELD TRIP 2022

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Workshop

The International Joint Workshop on Slow-to-Fast Earthquakes 2022 held in Nara, Japan, focused on the difference between "slow" and "fast" earthquakes. While for "fast" we mean regular earthquakes which cause worldwide destructions and trigger early warning systems, "slow" earthquakes include low-frequency earthquakes (LFEs), tectonic tremors, very low-frequency earthquakes (VLFEs), and slow slip events (SSEs).

A thorough overview of the two phenomena was given by the first keynote speaker, Dr. Ide. He suggested considering the slow earthquakes as manifestations of a single slow deformation process. For instance, a cluster of tremor/LFEs can be seen as an SSE. The rupture process of both fast and slow events may be self-similar with scale-invariant stress drop and energy, making the distinction of these events very challenging at the early stage of rupture propagation. A difference between the two processes seems to be the different scaling of maximum seismic moment magnitude with respect to duration. For example, the moment magnitude scales with earthquake duration for slow earthquakes, while the cube of duration for fast earthquakes. However, the most fundamental difference between fast and slow earthquakes may be the governing equation coupled with the friction/fracture equation: wave equation and diffusion equation for fast and slow earthquakes, respectively. Diffusional mechanisms are various and dependent on regional environmental conditions. Hence, slow earthquakes appear diverse.

A concept that has been discussed extensively during the workshop is the importance and role of heterogeneities. These heterogeneities may be lateral and vertical variations in Earth properties both in laboratory experiments (Dr. Faulkner), numerical modeling (Dr. Elbanna), and in nature (Dr. Townend). Another type of heterogeneity may be related to variations in fault frictions (Dr. Kaneko) or the presence of asperities with different sizes and geometry along the fault interface (Dr. Aochi).

This wide range of heterogeneities seems to play a crucial role in influencing the type of slip behavior. While the first day of the workshop was focused more on the terminology of the fast and slow earthquake (features and scaling), the importance of heterogeneity, and the role of slow phenomena (Dra. Mouchon, Dr. Ohyanagi, and Dr. Cruz-Atienza), the second day started off with a focus on new techniques to better monitor these seismic events.

These new techniques include distributed acoustic sensing (DAS) and fiber optic sensing (Dr. Zhan and Dr. Li, Dr. Araki, and Dr. Chen), which can resolve higher frequency signals than the standard seismometers, and the potential use of machine learning for more accurate seismic detection of slow phenomena (Dr. Rouet-Leduc, Dr. Chiu, Dr. Constantino). The afternoon session concentrated on the use of numerical modeling to infer the current state of the Nankai subduction zone (Dra. Sherrill, and Dr. Noda and Saito), and the use of seismic reflection for

inferring fault geometry and 3D heterogeneous structure (Dr. Tsuji, and Dr. Bassett), which may control different slip behavior along the trench.

Lastly, the third day focused on the geological constraints of slow and fast earthquakes. The geologic record of exhumed rocks seems to indicate the presence of a fluid-rich source in proximity to the area of slow events. Both geological and geophysical observations suggest the importance of the fluid-rich and high-pressure region for the slow slip and the tremor source region (Dra. Behr, Dr. Condit, and Dr. Kaneki). Besides the geologic record, Dr. Tanaka suggested using temporal variations in gravity anomaly to quantify the presence of water in the region of slow slip events in Nankai and Cascadia.

Field trip

The goal of the two-day geological field trip was to observe several outcrops of the Median Tectonic Line (MTL), which may have recorded a multi-stage faulting history of brittle-ductile deformation due to island-arc collision. Unfortunately, the entire field trip was affected by the typhoon Nanmadol bringing heavy rains and strong winds in the southwest of Japan (Figure 1).

Figure 1: Heavy rainfall during the field work in Matsusaka due to typhoon Nanmadol.

On the first day we observed outcrops of MTL in Matsusaka that experienced shallow brittle deformation (geologic fault contact, Figure 2) and deeper plastic deformation.

Figure 2: Example of brittle deformation along the MTL represented by the fault contact.

On the second day, we moved to the east to the Ise, where outcrops of high-pressure metamorphic rocks of the Sanbagawa Belt and the tectonic mélange of the Kurosegawa Belt formed at the subduction plate boundary (Figure 3).

Figure 3: Outcrop of high-pressure metamorphic rocks with quartz veins of the Sanbagawa Belt at Arashima Beach.