Long-term Research Visits (Project No.: 29L-02)

Project title: Investigating Earthquake Triggering during the 2016 Kumamoto sequence -Evaluating Hazards of Multiple Events-

Principal Investigator: Margarita Segou

Affiliation: British Geological Survey

Name of DPRI collaborative researcher: MORI, James Jiro

Name of visitor (Affiliation): Margarita Segou (British Geological Survey)

Period of stay: Feb 26, 2018 ~ Mar 30, 2018

Location of stay: Disaster Prevention Research Institute of Kyoto University

Number of participants in the collaborative research: 3   (2 DPRI and 1 non-DPRI staff)

  - Number of graduate students: 2 students (1 Master and 1 doctoral student)(Included number)

  - Participation role of graduate students [The students help with the data organization and run programs for testing the triggering effectiveness]

Anticipated impact for research and education

> The outcomes of this research should provide a better understanding of the realistic conditions for which active faults interact and trigger sequences of multiple earthquakes. This information will reduce the uncertainties of current physics-based forecasting. Providing such robust scientific information for on-going hazards, such as an aftershock sequence, is critical within the first hours to support informed decision-making, design proactive actions and earthquake mitigation plans. Also aftershock sequences may last few months to years, so the information for the longer time period is important for major reconstruction efforts.

Research report

(1) Purpose

   This research project studies various aspects of stress conditions for triggering earthquakes. Both static and dynamic stresses are considered and their effect on triggering seismic events is evaluated.   The original objective was to examine the 2016 Kumamoto earthquake sequence and evaluate the effectiveness of static stress triggering from the two larger (M6.2, M7.0) events using standard methodologies that calculate the Coulomb Failure Function. As we studied and discussed these data, other interesting aspects related to dynamic triggering became apparent and were included in this study.

   We seek to: (1) improve the physics-based understanding of earthquake processes that lead to these large magnitude events within this sequence and (2) use this new knowledge for developing stress-based forecast models. We will achieve this by combining stress field estimates and laboratory confirmed friction laws in order to model how the faults in the broader area respond to stress perturbations.

(2) Summary of research progress

   Margarita Segou visited the Earthquake Research Institute of University of Tokyo on Feb. 28. She had discussions with Japanese researchers about her earthquake triggering studies.

   Margarita Segou visited DPRI from March 1 to March 30.

   She gave a seminar on March 12 with the title Testing Earthquake Links. The talk summarized her recent work about evaluating the triggering of earthquakes using static stress models, as applied to 2017 Mexico earthquake sequence and other examples of seismic activity from around the world.

   Most of the time at DPRI was used for obtaining and organization earthquake data for further analyses of the earthquake triggering, especially for the 2016 Kumamoto sequence. This included obtaining earthquake

catalogs, focal mechanisms catalogs, estimates of focal mechanism uncertainty, slip models for two main Kumamoto earthquakes, waveform data for some of the larger events and distribution of the regional stress for the Kumamoto region in Kyushu. Using these data, preliminary tests were carried out to investigate the rate of aftershock occurence which is consistent with static stress changes caused by the mainshock slip distributions.

Another related topic about the possible triggering of small local earthquakes in the Northeast Kyushu region from large distant earthquakes, was discussed and appropriate data were gathered. This area was considered to have a relatively high potential of triggered earthquakes from distant earthquakes, because there were numerous events that were triggered immediately after the Kumamoto sequence. Combining the results of triggering due to large ground motions from large local earthquakes and weak motions from teleseismic events, can lead to a better understanding of the triggering process.

Margarita Segou also had various discussions with DPRI researchers about her current project for understanding the Mediterranean subduction zone. This seismogenic region has produced large earthquakes and tsunamis in the past, however, there are currently many important features are still not well understood, for example, the precise location and depth of the subducting plate and the current rates of subduction. Partly as a result of these discussions, a proposal was submitted to the European Consortium for Ocean Research Drilling (ECORD) for support of a workshop to discuss the Mediterranean subduction zone and plans for ocean floor seismic and GPS instrumentation.

(3) Summary of research findings

The visit of Margarita Segou was completed at the end of March, so the results of the triggering calculations are still being done. We have some preliminary results about the triggering of aftershocks from the Kumamoto sequence, which focus on exploratory tests for the earthquake triggering mechanisms. The tests considered traditional stress-change implementation based on optimal-oriented faults and the total stress field (regional stress and stress change from Kumamoto M=6.2 and M=7.0 events) in an effort to evaluate if aftershocks occur on (1) maximum stress planes or (2) previously reported rupture planes. The tests involve modeling of 78 earthquake ruptures with M>3.5 around 10 km depth. The preliminary results show: (1) about 25% of earthquakes are consistent with optimal oriented for failure faults, considering uncertainty of varying friction coefficients, (2) 1-2% of the earthquakes occur on maximum stressed planes, (3) 82% of the earthquake ruptures are consistent with the total stress method resolved on previously reported ruptures. These statistics are generally similar to results from other locations around the world.

(4) Publication of research findings

An abstract including the Kumamoto work was submitted to the 2018 European Seismological Commission meeting.

Segou, M., Parsons, T., Mori, J. and Chiarraba, C., A new technique to estimate fault potential and aftershock forecasts

A full paper is being prepared about the results for the Kumamoto sequence.