

Long-term observation of slow slip events for assessing earthquake generation models using borehole and cabled seafloor observatories.

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Abstract

To assess and improve earthquake generation cycle models, we propose that a long-term observation should be conducted over the entire area of large slow slip events ($>M6$) which have short recurrence time as a few years ($<10\text{yr}$) and locate in a depth where ordinary earthquakes occur (about 10-20 km). This observation should be used both borehole and cabled seafloor observatories for precise and near-field real time measurements and area coverage.

1. Earthquake generation models

In the last two decades, there has been a lot of progresses in studies on earthquake generation from laboratory experiments, field observations and theoretical investigations. We, now, accept that the process of earthquake generation cycle at plate boundaries consists of the following four elements (Matsu'ura 2002; Matsu'ura 2005) (Fig. 1);

- 1) Tectonic loading due to relative plate motion
- 2) Quasi-static rupture nucleation
- 3) Dynamic rupture propagation and stop
- 4) Stress redistribution and fault strength recovery

Many studies have been conducted on each element of the process, and proposed quantitative descriptions and/or governing equations of each element, and developed physical models of the earthquake generation cycle.

2. Long-term observation of slow slip events for earthquake generation cycle models

In the next decade, we should assess these models using real earthquake

cycles. To assess the models, we make a forecast of the next step by the models, then check this through observations, and make correction in the models. We should continue this revising process in several times. Therefore, it is very important to obtain data sets over entire earthquake cycle. Unfortunately, since ordinary earthquakes have recurrence time as a few hundred years, we can not observe entire earthquake cycle in the next decade. Recently, however, we found that some of slow slip events have short recurrence time as a few years, and locate in a depth where ordinary earthquakes occur (about 10-20 km, Fig. 2) (e.g. Ozawa et al. 2007), which means that some slow slip events and ordinary earthquakes exist in almost the same PT conditions. If we assume that the differences between the slow slip events and ordinary earthquakes are only in the third element (dynamic rupture propagation) of the earthquake generation cycle, and that frictional properties control the differences, we may apply the models of the earthquake generation cycle to the slow slip events. Long-term observations (over a decade) can obtain entire cycle of the slow slips and assess the earthquake cycle models.

3. Monitoring network with borehole and ocean bottom stations

In the observations, we expect the following phenomena:

- 1) For tectonic loading, slip deficits occur on plate boundaries.
- 2) For rupture nucleation, deformation due to a quasi-static slip at a small area about 1/10 of main slip is observed.
- 3) For rupture propagation, deformation due to main slip is observed.
- 4) For stress redistribution, aftershock and afterslips occur.

Some of these phenomena, like rupture nucleation, may generate only small deformation. So, we need to choose large slow slip events ($>M6$), and a sensitive monitoring network over the entire area of the slow slip events. To construct this network, it is essential to integrate ocean borehole observatories and sea floor observatories, which are connected by sea floor cables for power supply and real-time data transmission. Borehole observation provides high sensitive measurements using strainmeters, broadband seismometers, and tiltmeters due to near-field emplacement of the sensors. On the other hand, seafloor network of sensors such as a pressure gauge can cover wide region, which is also important to estimate the slip. It is useful that connection among the sensors on sea floor and in boreholes by seafloor cables for power supply and real-time data retrieve. Therefore we propose to construct the cabled

network using borehole sensors and seafloor sensors for geophysical monitoring of the target region.

References

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Matsu'ura M., Quest for predictability of geodynamic processes through computer simulation, Computing in Science and Engineering 7 (4), pp. 43-50, 2005.

Ozawa, S., H. Suito, M. Tobita, Occurrence of quasi-periodic slow-slip off the east coast of the Boso peninsula, Central Japan, Earth Planets Space, 59, 1241-1245, 2007.

Figures

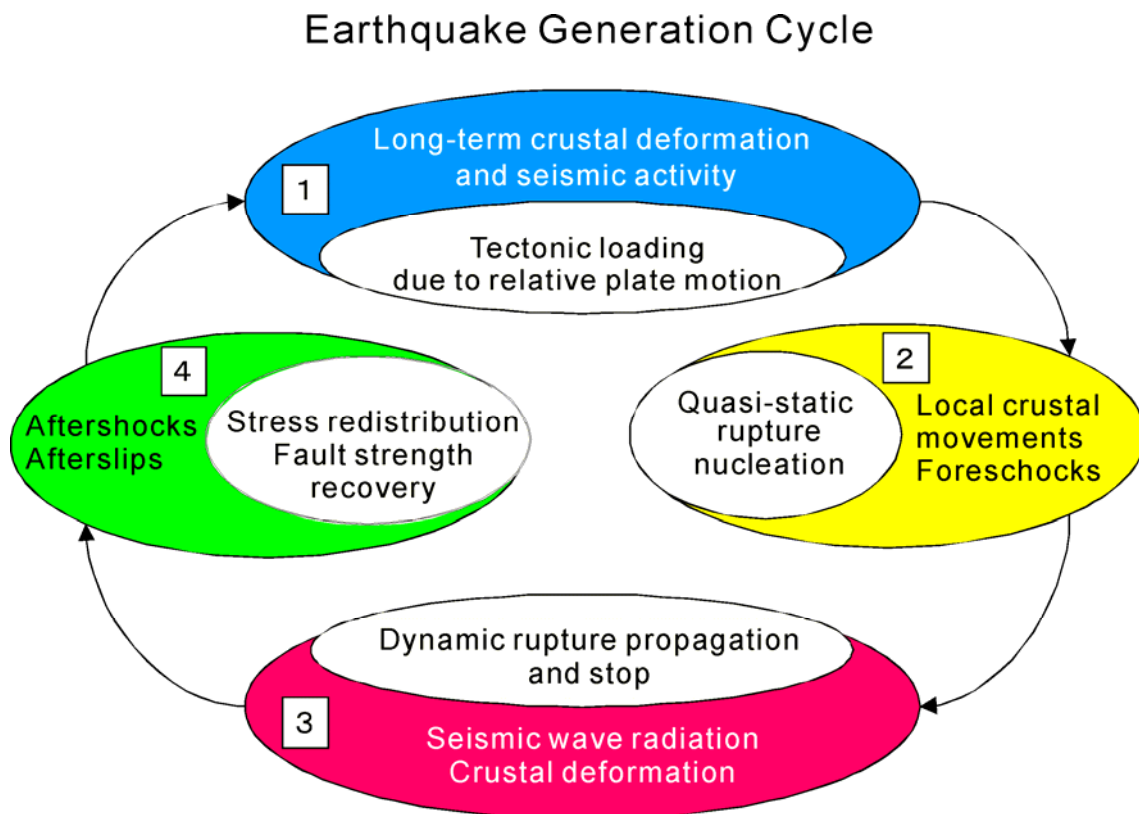


Fig. 1 Earthquake generation cycle

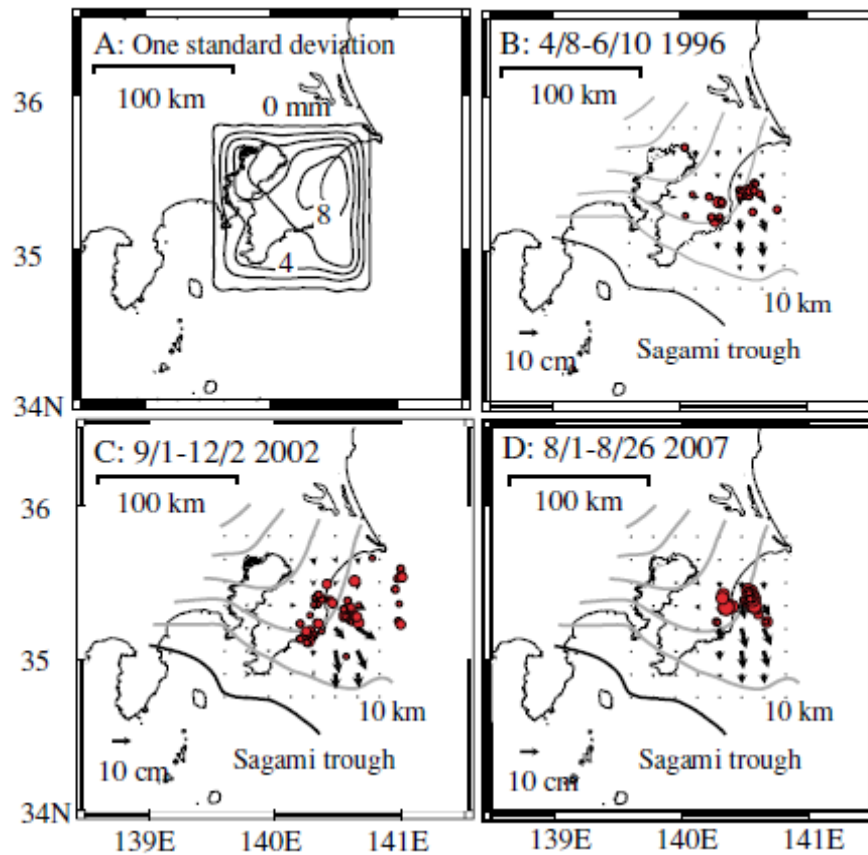


Fig. 2 Slow slip events at off Boso Peninsula, Central Japan (Ozawa et al. 2007). Solid arrows indicate slips on the plate boundary between the Philippine Sea plate and the North American plate. Red circles indicate epicenters during the slow slip events. Magnitudes of each slow slip event are Mw6.4 for 1996, Mw6.6 for 2002, and Mw6.6 for 2007.