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Identification of the Nucleation Stage of Natural Earthquakes by Monitoring Microcracks

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Identification of precursory phenomena is essential to the development of a method for forecasting earthquakes (Scholz, 2002). For the imminent forecasts, however, no confirmative phenomena have been identified which might be practically applied. There are numerous approaches to identifying the nucleation stage through seismic, electromagnetic, geodetic, and hydrologic approaches. Especially, the foreshock or acoustic emission have been taken to be most plausible phenomena on the basis of investigation of seismic activities (e.g., Jones and Molnar, 1979; Maeda, 1999) and rock rupture experiment (e.g., Yoshida et al, 1998). However, we have no knowledge to define the nucleation phase in the preparatory process of the natural earthquake.

The acoustic emission technique has been widely used in the geotechnical engineering field. Concerning natural earthquakes there are only several pioneering studies to investigated field acoustic emission activities (Hattori, 2003). Those researches indicate that the activity is high about a half-day both before and after the earthquake occurrence, but detailed characteristics defining the nucleation phase has not yet been obtained.

We have been observing electric field variations to find anomalous phenomena for prediction. The detection sensor is to measure vertical components of electric field by a special antenna made of a casing pipe ranging 100- 1,800 m deep. The system has been proved to be highly robust to both meteorological and urban noises. Among various kinds of variations, the particular pulse-like variations similar to the time evolution of geyser (GUV) have been almost always detected in association with seismic swarms, volcanic eruption near the observation points (Fujinawa et al., 2001). The signals have never been detected in a normal state. And the phenomena are suggested to be induced by an electro-kinetic effect (e.g., Mizutani et al., 1976).

The new detector has higher dynamic ranges in frequency bands of DC (0-1.45 Hz) and AC (1.45 Hz- 9 kHz) and in signal strength. The observation started on 3, March 2011 at Hasaki in the Ibaraki Prefecture about 300 km south of the epicenter of the Tohoku Earthquake.

Here we show that there are typical pulse-like waveforms associated with cracks just before and after the Great Tohoku Earthquake on March 11, 2011. Those variations are grouped by time constants: A type with duration of several to several ten minutes same as the GUV (Fig. 1a), B of several ten milliseconds, and C of several hundred micro seconds (Fig.1e). The B- type variations are sub-grouped into three by waveform: B-1 of similar to the GUV but in the stepped decay in relaxation phase (Fig. 1b), B-2 of wave packet similar to seismic wave (Fig.1c), and B-3 of a combination of B-1 and B-2 (Fig.1d). Different types of electric waveforms are suggested to be corresponding to crack rupture modes of tensile and shear, and to be generated by induced confined water movement through the electro-kinetic effects (e.g., Mizutani et al., 1976) on the ground of previous investigations on laboratory experiments.

Before the Tohoku earthquake there appeared 163 type B variations except one events of A type, and type A and C events after the earthquake. The number of B type events started to increase on the 7th, had a prominent peak on the 9th, a pronounced lull on the 10th, and recovered considerably on the morning of 11th. This time evolution had a strong similarity with that of acoustic emissions just before rupture in the rock experiment and the averaged evolution for many cases of the pre-shocks (Varnes, 1989). In the DC range only one A-type appeared during the preparation stage: almost all occurred after the main shock.

The shorter period variation of Type B is suggested to be a key phenomenon to identify the nucleation stage. The signal can be detected for natural earthquake by monitoring vertical components of electric fields using special deep long antenna.

Keywords: earthquake precursor, nucleation stage, microcrack, electric phenomena, confined water

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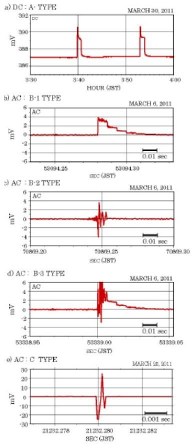

Figure 1

a) Waveform of the pulse-like particular signals in the DC band (type A). Type A has a duration of several tens of seconds to several tens of minutes, and a height of about 2–3 mV. The form was first identified by the temporally rapid recording at the time of volcanic eruption activities in 1990 at Izu-Oshima (Fujinawa *et al*, 2001). Afterward, we detected similar signals at almost cases of nearby volcanic eruption and seismic swarms (11).

(b) Type B-1 waveform of the pulse-like signals in the AC band. The form is very similar to type A except that it is of smaller duration (several tens of ms) and shows several steps in the process of relaxation.

(c) Type B-2 waveform of the pulse-like signals in the AC band similar with a wave-packet. There is no coda phase, in contrast to seismic waves. A similar pattern was detected in the case of wetted granite specimens with a dominant frequency of 500 kHz (Yoshida *et al,* 1998). The S-P time was about 30 ms, suggesting an epicentral distance of 270 m. Several examples of events having P,S phases can be seen. The absence or very slight appearance of a P-phase indicates an epicentral distance larger than a few km.

(d) Type B-3 waveform in the AC band with a waveform compounded by type B-1 and type B-2.

(e) Type C waveform in the AC band. The waveform is the same as type B-2, but its amplitude is very large: 20–30 mV, with some 10 times larger than those of type A and B.