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Abstract 1-10p

Micro Cracks Associated with the Great Tohoku Earthquake

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Identification of precursory phenomena is essential to the development of a method for forecasting earthquakes [1]. For the imminent forecasts, however, no confirmative phenomena have been identified which might be practically applied to earthquake forecasting with high confidence.

There are numerous approaches to evaluating and identifying candidates of precursory phenomena in the nucleation stage. Especially, the foreshock or acoustic emission have been taken to be most plausible phenomena expected to appear just before the main rupture of accelerated accumulation of stress and/or strain on the ground of investigation of seismic activities [2, 3] and rock rupture experiment [4,5]. However, we have not yet obtained enough knowledge about diagnostic character of individual foreshock providing clue to define the nucleation phase [1].

We have been observing electric field variations related with earthquake occurrence to find anomalous phenomena to be applied for prediction from the view point of the IASPEI subcommission [6]. The detection sensor is to measure vertical components of electric field by a special antenna made of a vertical casing pipe that is set into a borehole. We have been using 13 boreholes in the central japan ranging from 100 ～ 1,800 m deep since 1989 [7,8]. The recording frequency is in three bands: DC, ULF and ELF/VLF. It has been proved that the system is highly robust to both meteorological and urban noises.

The particular pulse-like variations similar to the time evolution of geyser (GUV) have been detected in association with seismic swarms and volcanic eruption activities. The signals have never been detected in a normal state, and have been observed in almost all volcanic eruption activities and seismic swarms occurring near the observation points [7, 8]. The phenomena have been suggested to be induced by an electro-kinetic effect [9].

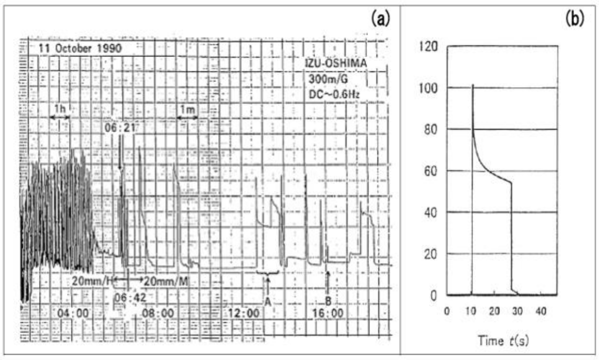

Figure 1
(a)Records of electric field anomalies related with the small volcanic activities in the Izu-Oshima Island in 1990 by the borehole antenna [10]. Slow speed recording show pulse like signals(left part of (a), but rapid recording show the particular waveform similar to the geyser height evolution.
(b) typical confined pressure change to explain the electric field changes based on the electro-kinetic effect [18].

We installed a new detecting instrument of larger dynamic ranges in March 2011 : in frequency of DC (0-1.45 Hz) and AC (1.45 Hz- 9 kHz) , and in signal strength of 16 bits.

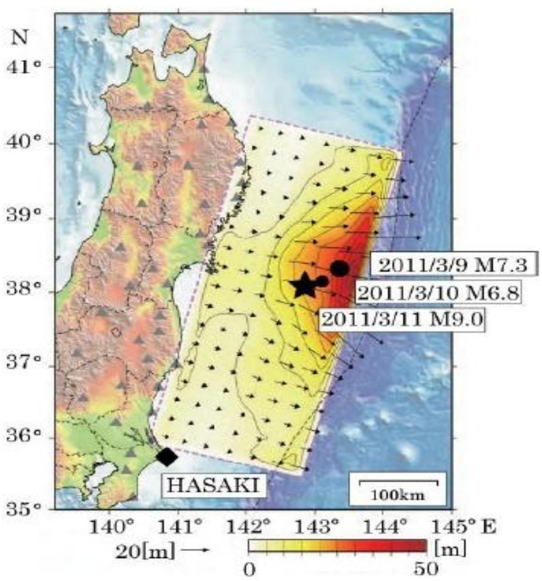

Fig. 2: Geographical relationship between the observation site Hasaki [18, 20] and the rupture zone and displacement distribution of the Tohoku Earthquake (revised from NIED [12]).

The observation started on 3, March 2011 at Hasaki (now Kamisu City, Ibaraki Prefecture) about 300 km south of the epicenter of the Tohoku Earthquake (Fig. 2).

The large dynamic range has made it possible to identify particular electric field variations. Here we show that there are four typical pulse-like waveforms of electric field variations associated with micro-cracks just before and around the Great Tohoku Earthquake on March 11.

Different types of electric waveforms are suggested to correspond to crack rupture modes of tensile and shear, and to be generated by confined water movement through the electro-kinetic effects [9] on the ground of previous investigations on laboratory experiments [5,11-13].

Figure 4 shows the time evolution of the number of the pulses. In the AC range, there appeared only the type B variations before the great earthquake (3.11), and type C after the earthquake. As to B type, the number started to increase on the 7th, had a peak on the 9th, a pronounced lull on the 10th, and

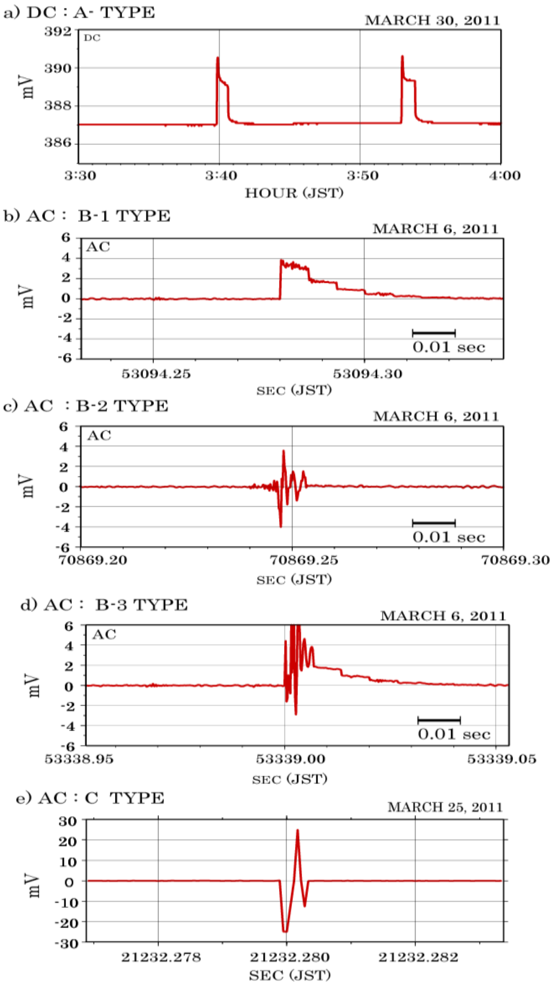

Figure 3

Wave-form of the pulse-like particular signals in the DC and AC bands.
a) type A variation is the same as observed at the time of volcanic eruption activities and seismic swarms (GUV) [3, 5].
b) Type B1 is very similar to GUV except the smaller duration of several tens of ms and several steps in the process of decreasing compared with GUV. Average amplitude is several milivolts. The signal duration of B types is much larger than that of the lighting discharge of tens of micro seconds, and the waveform is also different.
c) Type B-2 is a wave-packet with a carrier frequency of a few hundred Hz and duration of several ms.
d) Type B-3 is the compound of B-1 and B-2.
e) Type C wave-form in the AC band. The signal duration of the anomalies is some 0.5ms, and carrier frequency is some 5kHz, but amplitude is 20-30mV, much larger than those of type A, B.

recovered considerably on the morning of 11th till the occurrence of the earthquake. The evolution had a strong similarity with that of acoustic emissions just before rupture in the rock experiment [1, 4, 5], and that of the pre-shocks before the main shock [3, 14] .

The phenomenon is suggested to be one of the most plausible candidates for an imminent prediction satisfying many of the conditions required for the precursor. Previous field observation of acoustic emission indicated that there are increased acoustic emission activities during some half days before and after main shock peaked at the time of main shock [15-17]. We provide a useful data to be used for imminent prediction of the earthquake. The discussion about the possibility of earthquake prediction should be based on the observation of real phenomena with enough usability for practical application.

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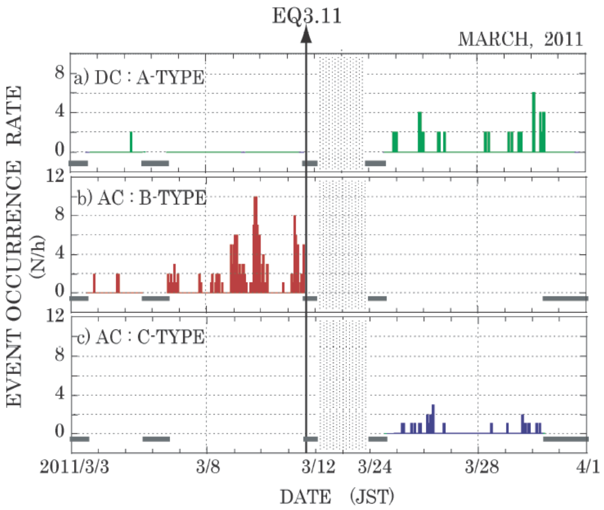

Figure 4:
Time evolution of the DC and AC band pulse-like signals. a) A-type in Figure 3. b) B-type inFigure 3, c) C-type in Figure 3. Only one A-type variation appeared during the preparation stage, and almost all occurred after the main shock (Figure 4a). The C-type variation occurred also after the main shock suggesting those are induced in the process of relaxation of sudden change of strain and/or stress in the rupture zone. The confined water is thought to play an important role in generation of micro-crack and observation by the electromagnetic method. The micro-crack is suggested to be remotely detected because of the seismo-electric interaction [18-20].

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