A summary of earthquake swarm activities in the inland area of Japan induced by the M9 Tohoku-oki earthquake

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After the 2011 Tohoku earthquake, a lot of types of earthquake swarm activities occurred in the crust of Japan Islands. I would like to categorize them, depending on depth ranges, magnitudes, volcanoes and delay times, and to try to catch controlling factor of the earthquake swarm activity,
We are able to categorize them as below.
Category 1: Earthquake swarms at the depth range shallower than 10 km in volcanic areas such as Tateyama-Kurobe and Yakedake-Norikuradake areas in the Hida Mt., Nikko-Shirane Mt. and Hakone Mt. in the Kanto district in central Japan. They were triggered by giant seismic waves of amplitudes larger than MPa within a few minutes, coda waves of periods of 15 s to 20 s of amplitudes of a few hundred kPa within around 30 minutes and long period surface waves of a few hundred seconds of amplitudes of a few kPa between 1.5 and 3.5 hour later after circulating the Earth.
Category 2: Those at depths shallower than 10 km induced in areas of quaternary volcanoes such as Dainichi Mt., Kosha Mt. and Moriyoshi Mt., initiated days and months late after the Tohoku earthquake.
Category 3: Those at depths of 10 km to 15 km in non-volcanic Kita-Akita area in Akita Pref. and Senda-Okukra dam area in Miyagi Pref., initiated days and months late after the Tohoku earthquake.
Category 4: Those at depths of 5 km to 15 km in volcanic areas in the territory of the Philippine sea plate such as Fuji Mt. and Niijima and Kozujima islands area.
Based on the numerical simulation of temperature-dependence of solubility of water of amorphous slice, Bodnar and Costain (1991) derived the solubility in water of amorphous silica at the vapor pressure of the solution to find negative temperature dependence between around 350 C and 550 C in a geopressure range of upper crust.
Kusakabe et al. (2003) proposed the hypothesis that the low density of 2.1 gr/cm3 to 2.2 gr/cm3 low velocity layer at depths from 2 km to 7 km obtained by gravity anomaly data at the deepest part of the Tateyama-Kurobe area (Gennai et al., 2003) is the rock-water mixed reservoir between around 350 C and 550 C and the top of the reservoir should be the self-sealing layer caused by the negative dependence.
The earthquake swarm in the Tateyama-Kurobe at depths between 0 km and 3 km is supposed to be due to the fluid up-welling diffusion from open seams facilitated by strong seismic waves of the Tohoku-oki earthquake.
The same can be said for other earthquake swarms of the Category 1.
In cases of earthquake swarms in non-volcanic areas of the Category 2, temperature reaches to 350 C at depths of around 15 km under the normal geothermal gradient in non-volcanic regions. We can suppose that there could be rock-water reservoir not associated with volcanic magma under the 350 C depth and the fluid diffusion as same as category 1 could occur to induce earthquake swarms.
As the silica-rich fluid up-wells along faults triggering micro-earthquakes, temperature decreases to deposit solid silica to seal the faults to suppress the growth of faulting. Thus, non of small faultings within any of swarms of Categories 1 and 2 could become earthquakes larger than M5.
According to the scenario we proposed above, earthquake distributions of swarms of Category 3 shallower than 10 km suggest that relatively young quaternary volcanoes whose activity ended a few hundred thousand years ago are relatively hot.
A lot of problems remains to be solved. The largest one should be what is controlling factor of delays of a few days to a few months of starting of swarm activities. Earthquake swarm of Category 1 started within 30

minutes after the M9 event. Those of Category 2 to 4 did a few days or a few months later.
Anyway we can say as summary that, giant seismic waves yielded seams to the self-sealing layer to have silica rich fluid up-welling to provide a lot of chance of earthquake faulting but non of them can grow to be large earthquake of M5 or larger due to the sealing effect by solid silica deposited under lowered compressional stress in the crust of Japan Islands.
References

Keywords: induced earthquake swarm, rock-water mixed layer, self-sealed layer

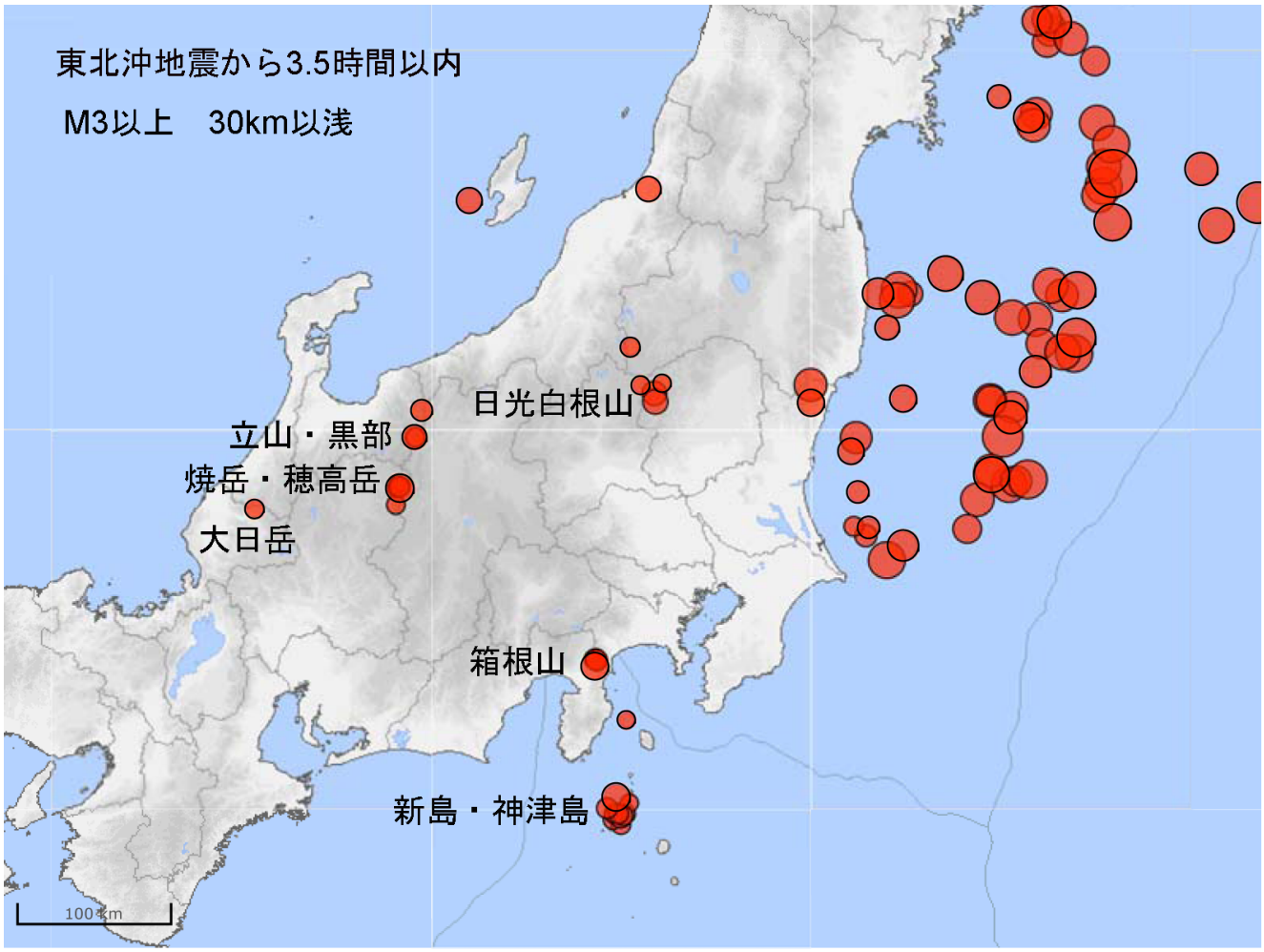

Fig.1 Earthquakes of M3 or larger at depths of 0 km to 30 km for 3.5 hours from the origin time of the Tohoku earthquake. Plotted by seismic intensity database of JMA web site.

