Prediction of large earthquakes off Miyagi Prefecture by observation of groundwater temperature in a deep borehole

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To predict future large earthquakes off-Miyagi prefecture, we have observed groundwater temperature in a borehole 1200m deep since June 20th, 2004. This borehole crosses the Nagamachi-Rifu fault zone at 820m depth. This fault is a reverse active fault with northeast direction and northwest dip. Assuming this fault zone as a natural amplifier of crustal strain, we set a quartz temperature sensor with the resolution of 0.0002 deg. C at 820m depth. The data acquired every minute has been transferred remotely to a PC in our laboratory.

Since the observation started, we were annoyed for a long time by mysterious intermittent temperature fluctuations of two types; one is of a period of 5-10 days and an amplitude of ca. 0.1 deg. C, and other is of a period of 11-21 days and an amplitude of ca. 0.2 deg. C. Then we checked up the sensor and the instruments to confirm them working normal. Normal working of our observation system was confirmed also by the pumping up test and the systematic temperature changes associated with changeing the depth where the sensor was set. Thereafter we examined the possibility whether natural convection occurs in the borehole by using the product of Grasshof number and Prantl number. Since this value suggested the occurrence of natural convection, we set polyurethane stoppers above and below the sensor. Thereafter, the mysterious fluctuations of the short period disappeared.

The groundwater temperature changed in sync with earth tide. The amplitude is ca. 0.001 deg. C on the days of the full moon and new moon. Using the crustal strain by earth tide (ca. 2∗10ˆ-8 strain) as a measure, the resolution limit of our observation system was estimated at 1∗10ˆ-8 strain (0.5kPa), even if background noise is taken into the consideration. The bottoms of the temperature fluctuations always delay about 6hours relative to peaks of earth tide. The 6 hours time lag means that our observation site rotates already 90 deg. against the moon. Since at this positional relation tensile stress near the half of the tidal stress acts on the NE-trending Nagamachi-Rifu fault. Therefore, the temperature drop after the calmination of the moon is likely to be attributed to the relaxation of the fault plane contact and the suction of water into the interstices.

How small earthquakes off Miyagi Pref. can be detected by our observation system? We examined this problem by MICAP-G, a computer simulation code released by Okada (1992) and Naito & Yoshikawa (1999). Using the source parameters for a future off-Miyagi Pref. earthquake (The Headquarters for Earthquake Research Promotion, 2003), and inputting the unit fault slip (1 m), we calculated extensional strain at the observation site at about 3x10ˆ-7 strain. Based on this calculation result and the resolution limit of our temperature observation system, it is estimated that our system can detect earthquakes larger than about M6.

After listed up all earthquakes which shook Sendai city at intensity larger than III, we eliminated the earthquakes which occurred when the sensor was not set or the convection occurred in the borehole. The earthquakes whose epicenter is far more than 150 km or which occurred within the subducting slab also were eliminated. The remains are only nine events, among which the earthquake off Miyagi Pref. on Dec. 2, 2005 (M6.6) is the largest. We detected successfully the precursory temperature change for this earthquake. About 2.5 hours before the main shock, groundwater temperature began to go down, and it attained to 0.003 deg. C at about 1 hour before the main shock. Thereafter, the temperature turned to go up, and showed a sharp peak (0.002 deg. C) at 10 minutes after the main shock. Judging from the temperature response to earth tide, this temperature decrease of 0.003 deg. C corresponds to an earthquake M6.6, suggesting that this earthquake was associatedc with an aseismic preslip with nearly same seismic moment as the main shock.