# Scientific survey and monitoring of the off-shore seismogenic zone with Tokai SCANNER: submarine cabled network observatory for nowcast of earthquake recurrence in the Tokai region, Japan


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*Abstract* - **Existence of fluid on seismogenic zones has a key role on great earthquakes. The electrical conductivity structures obtained by electromagnetic survey across the great earthquake zones show that the seismically locked zones correspond to the low conductive zones. The low conductivity is possibly interpreted as relatively low fluid content. For more discussion on the role of fluid to earthquake occurrence, we have just started an electromagnetic and seismological monitoring by using long submarine cables off Toyohashi, the southwest Japan Island. The cables are located on the Tokai seismogenic zone, where both slow-slipping and locked zones are obvious by GPS observation. Here, we introduce the recent and upcoming situations of the project.**


## I. INTRODUCTION

Existence of fluid on seismogenic zone has a key role on occurrence of great earthquakes because high pore pressure in a fault zone allows sliding at low shear stress (e.g., Blanpied et al., 1992). In fact, Fujie et al. (2002) found in the Japan Trench region that large amplitude reflected waves generated at the subducting plate boundary were observed at low seismicity region and vice versa. The heterogeneous distribution of reflectors may be attributed to heterogeneous fluid distribution on the plate boundary, and may indicate the role of fluid on the earthquake occurrences. However, other factors can explain such reflectors, so that independent geophysical surveys sensitive to fluid are required for further discussion. Electromagnetic surveys have revealed fluid distribution in seismogenic zones (e.g., Unsworth et al., 2000) because enhanced electrical conductivity at subsolidus temperatures is principally controlled by the presence of water. In this study, we briefly review a newly obtained conductivity structure across the off-shore seismogenic zone. In addition, we introduce an upcoming scientific survey and monitoring of the off-shore seismogenic zone with a submarine cabled observatory.

## II. CONDUCTIVITY STRUCTURE AROUND THE 1944 TONANKAI EARTHQUAKE ZONE

The 1944 Tonankai earthquake (M 7.9) in the Kumano Basin and Nankai Trough, off the Kii peninsula, southwest Japan is one of the typical mega-thrust earthquakes recurred along subduction zones. Land and marine magnetotelluric surveys in the Kii peninsula, the Kumano Basin and the Nankai Trough were carried out in 2002-2004. On the basis of the marine data, Goto et al. (2003) estimated an electrical conductivity model below the seafloor, in which the Philippine Sea plate has a conductive oceanic crust before subduction. As the plate goes down the Kumano Basin, the conductivity becomes low at the depth of 10 km below the seafloor, which approximately coincides with the up-dip limit of the Nankai mega-earthquake zone. Meanwhile, Kasaya et al. (2005) tried a joint modeling by using land and marine data, and their preliminary model shows that the Philippine Sea plate becomes more conductive (with 0.1 S/m) again below the depth of 30 km, around the down-dip limit of the earthquake zone. In the other words, the rupture zone of the 1944 Tonankai Earthquake corresponds to a less conductive zone than its shallower and deeper zones on the subducting plate. Similar relationship between conductivity structures and seismically locked zone is reported by the Atotsugawa fault (Goto et al., 2005), the North Anatolian fault (Oshiman et al., 2002), and the San Andreas fault (Unsworth et al., 1999).

## III. MONITRING THE OFF-SHORE SEISMOGENIC ZONE WITH A SUBMARINE CABLE

Although electromagnetic surveys can show less fluid condition around seismically locked zones, there is no information how fluid can act on occurrence of great earthquakes: for example, whether highly-pressurized deep fluid moves into seismically locked zones and reduces strength of locked zones, or not. One of the best ways to test such hypothesis is electromagnetic monitoring around seismically locked zones. Of course, other geophysical monitoring should be included such as seismic wave, crustal deformation, sub-seafloor temperature and so on.

Here, we introduce an observation project named Tokai-SCANNER: Tokai Submarine Cabled Network observatories for Nowcast of Earthquake Recurrences. The observatory with the off-Toyohashi cables (Fig. 1) has been just constructed on April, 2007 in the Tokai region, Japan, where a locked plate boundary on the subducting Philippine Sea plate is clearly recognized (Sagiya, 1999). In addition, a slow slip on the plate boundary is recently found (Ohta et al., 2004: Fig. 1). Such a slip makes a stress concentration near the boundary between the locked and slipping zones, so that the boundary region has a potential of an initial rupture of the next Tokai earthquake. The off-Toyohashi cables (Fig. 1) were originally a part of JIH (the Japan Internet Highway) installed by KDDI for data transfer and telecommunication. Due to a leakage trouble, these cables were retired and were transferred to JAMSTEC in 2006 for scientific use. The cables are located on both the locked and slipping zones of the Tokai region, so that they can be used for a best facility to monitor physical properties around the plate boundary.

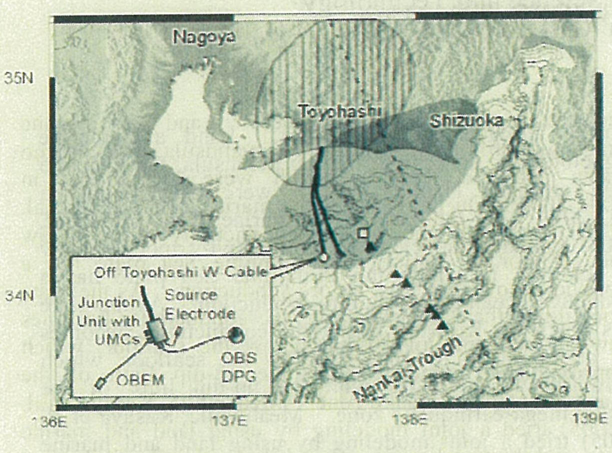


Fig. 1. Location of the off-Toyohashi cables (thick lines). Gray and line hatched areas: seismically locked and slow-slip area (Ohta et al., 2004). A dashed line: seismic survey by Kodaira et al.(2004). A rectangle: location of EFOS. A circle: location of Junction Unit. Triangles:: self pop-up OBEM sites.

The details of the scientific observation at the Tokai-SCANNER are introduced here. This observatory is used for active and passive geophysical monitoring. As an active method, a controlled source electromagnetic monitoring is conducted to detect conductivity variation (indication of fluid migration) around the plate boundary. The off-Toyohashi W-cable is used as a transmitting dipole source with two electrodes located at 0km (coast line) and 50km (off shore), respectively. For the receivers, the off-Toyohashi E-cable is available. The cable has an electric leakage at 5km off shore. The leakage ends the telecommunication, but gives us a chance for electrical potential observation on seafloor. The measurement of voltage difference by using the off-Toyohashi E-cable as a 5km dipole was started from 2004 and has been continued by Tokai Univ. The artificial electric signal from the W-cable can be received by the E-cable. In addition, the long-term electric field observation system (EFOS), originally developed by Univ. Tokyo can be the receiver. Although the EFOS is not connected to the submarine cables, it can record the seafloor electric field continuously for several years. The EFOS is installed on January, 2007 by the JAMSTEC ROV "Hyper-Dolphin" with a receiving dipole with length of 300m (Fig.1). Numerical calculations show us that apparent resistivity values daily obtained can be changed if the high conductive zone on the plate boundary is revealed. Therefore, the submarine cables are useful tools for monitoring fluid around the plate interface.

As a passive monitoring, we connected various sensors to the tip of the off-Toyohashi W-cable; ocean bottom seismometers (OBS), differential pressure gauges (DPG), ocean bottom electromagnetometer (OBEM), thermometers and so on. For connecting these sensors, the Junction Unit (JU) with five underwater matable ROV connectors is attached to the off-Toyohashi W-cable (Fig.1). These sensors are sensitive to off-shore micro earthquakes, slow-slip events, seafloor upward/downward movements, heat transportation with fluid flow, geomagnetic variation associated with stress changes and self-potential variation with fluid pressure changes. Such a package of various geophysical sensors will help us to discuss on the detailed process before/at/after the earthquakes. Especially, the multidisciplinary observation is useful for signal and noise estimation of those phenomena related to earthquakes.

## IV. 2007 ELECTROMAGNETIC SURVEY IN TOKAI REGION

One problem using long cables for monitoring is low spatial resolution. Before the monitoring, we suggest a conventional electromagnetic survey with self pop-up ocean-bottom electromagnetometers (OBEMs). For imaging the crustal structure with higher resolution, we newly developed the small short-term OBEM (Fig. 2). It consists of one deep-sea glass sphere, a three-component fluxgate magnetometer, voltmeters with Ag-AgCl electrodes, tilt meters and an acoustic release system common to the Japanese self pop-up OBS. One feature of the OBEM is four long arms for electrodes. For the speedy pop-up and the easy recovery operation, these arms are folded when the OBEM is launched from the seafloor (detailed in Kasaya et al. 2006). A number of the short-term OBEM can be handled as array observation even with a small fisher boat.

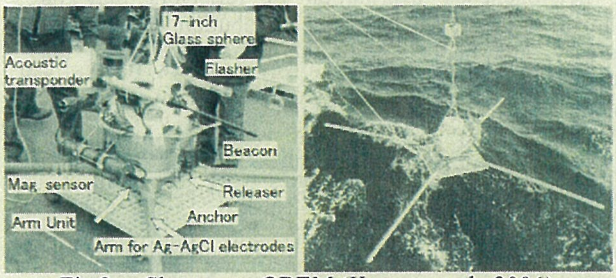


Fig.2. Short-term OBEM (Kasaya et al., 2006). Deployment at the NT07-01 cruise on January, 2007.

An electromagnetic survey of the Tokai seismogenic zone with the OBEMs was carried out on January, 2007. Three OBEM and three OBE (without the magnetometer) were deployed at the NT07-01 research cruise by R/V Natsushima, JAMSTEC. The OBEM sites are shown in Fig. 1. After one-month seafloor observation, all six instruments were successfully recovered at the NT07-03 cruise by R/V Natsushima on February, 2007. The obtained fluctuations of natural electromagnetic field can be analyzed with the magnetotelluric method and allow us imaging the conductivity structure around the Tokai seismogenic zone such as reported in Kasaya et al. (2005).

Although the OBEM survey shows us a "snap-shot" of the crustral structure, it is useful for rough estimation where anomalous conductivity variation detected by electromagnetic monitoring with the off-Toyohashi cables locates. In addition, the OBEM can receive the controlled electromagnetic signals from the off-Toyohashi W-cable in future. Although the lifetime of the short-term OBEM on seafloor is limited (less than three-months), such a combination of the Tokai-SCANNER and mobile OBEM survey is an effective tool for monitoring the seismogenic zone, as summarized in Fig.3.

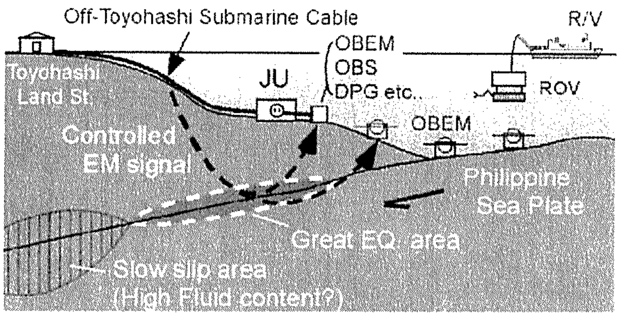


Fig. 3. A concept of the Tokai-SCANNER and "mobile" OBEM surveys. Short-term OBEM array recording the natural and controlled EM signals have higher spatial resolution and cover the Tokai-SCANNER with the long-term observation

## V. UPCOMING SITUATION OF TOKAI-SCANNER

Finally, we introduce the history and upcoming situation of the Tokai-SCANNER project, briefly.

- Jan. 2004: The off-Toyohashi cables were retired. No JUs and geophysical sensors were connected to the cables.
- Oct. 2004: The electrical potential monitoring with off-Toyohashi E-cable was started. The voltage difference between the sea earth at the Toyohashi land station and an electric leakage at about 5km off shore have been recorded.
- Jun. 2006: The off-Toyohashi cables was transferred to JAMSTEC.
- Dec 2006: JU, OBS, DPG, OBEM were developed and tested (Fig. 4).
- Jan. 2007: The short-term OBEMs were deployed at six sites, and the EFOS is deployed by the ROV (Fig.1). Also, by using the ROV, the seafloor video images and sub-seafloor temperatures were obtained near the end of the off-Toyohashi W-cable, planned location of the Junction Unit (JU) and geophysical sensors.
- Feb. 2007: All of the short-term OBEMs were recovered successfully.
- Mar. 2007: JU will be attached to the end of the off-Toyohashi W-cable.
- Apr. 2007: Several geophysical sensors (OBS, DPG and OBEM) will be connected to JU. Geophysical monitoring of the Tokai-SCANNER will be started. Three OBEMs will be deployed for recording natural EM fluctuations and the controlled EM signal from the off-Toyohashi W-cable. One EFOS will be recovered and re-installed, and another new EFOS will be deployed.
- July 2007: Three OBEMs will be recovered.

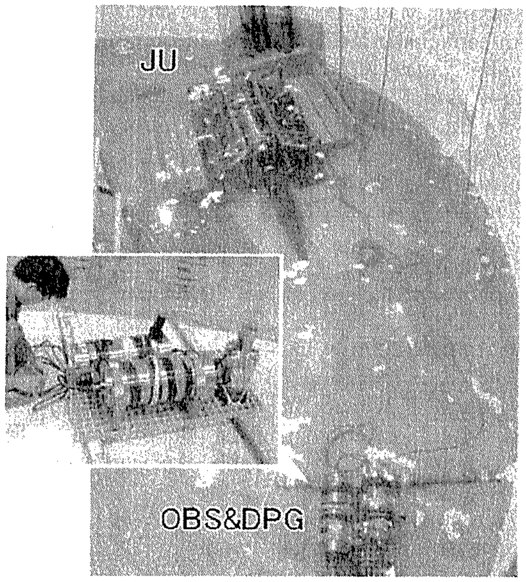


Fig. 4. Connection test between the sensors and the JU. No major problem was found. These sensors can record seafloor phenomena by off-shore earthquakes, tsunamis, crustal deformation and submarine groundwater flow.

The Tokai-SCANNER is a kind of frontier projects for the earthquake research with new technologies. Therefore, the prediction of the Tokai earthquake may be a different issue of the project. For example, if we detect the variation of the electromagnetic response function on the seafloor by using the controlled signal, further observation with a short-term mobile OBEM array may be necessary to estimate the location and depth of the anomaly. Also, the EFOS, a receiver of the controlled signal, is not connected to the submarine cables. However, nobody knows what kind of seafloor and sub-seafloor phenomena are revealed before, at and after the great earthquake. The multidisciplinary observation with active and passive methods seems to be a small spotlight to the undiscovered seafloor phenomena. If our geophysical monitoring will be proved to effective tool for earthquake predictions, more "spotlights" will be attached to submarine cables.


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