Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SCG058-P01 Room:Convention Hall Time:May 23 10:30-13:00

Evaluation of ULF electromagnetic phenomena during the 2002 and the 2007 slow slip events in Boso Peninsula, Japan

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The detection of electromagnetic perturbations prior to fault ruptures or volcanic eruptions has often been proposed as a simple and effective method for monitoring the crustal activities. Recently electromagnetic phenomena have been considered as a promising candidate for short-term earthquake prediction. And especially passive ground-based observation of ULF (ultra low frequency) geomagnetic signatures is considered to be the most promising method for seismo-magnetic phenomena study due to deeper skin depth.

In order to investigate the electromagnetic phenomena associated with crustal activities, a sensitive geomagnetic network has been established in Japan. At each station, three magnetic components and two horizontal electric components are observed. In this study, we have analyzed geomagnetic data observed during the 2002 and the 2007 slow slip events in Boso Peninsula, Japan.

According to previous studies, the geomagnetic signals at the frequency around 0.01Hz might be sensitive to underground activities. So in this research, we have applied wavelet transform analysis to the 1Hz sampling data observed at three magnetic observatories in Boso Peninsula (Kiyosumi, Uchiura, and Fudago). The signature at the 0.01Hz frequency band has been revealed and daily average energy has been computed.

In general, ULF geomagnetic signals observed on the ground mainly contain three parts: global signals originated from Ionosphere, artificial noises, and signals induced by underground activities. In order to minimum artificial noise, we only use the midnight time data (LT 0:00~3:00). And to remove influences of global magnetic perturbations, we have developed another method to obtain reliable background based on principal component analysis (PCA). Three standard geomagnetic stations (Memambetsu, Kakioka, and Kanoya) operated by the Japan Meteorological Agency have been selected as reference stations and PCA method has been applied to the yearly energy variation of the 0.01Hz signals at the three stations. The first principal component which contains more than 95% energy is considered to be global background.

After comparing the results at the stations in Boso Peninsula with global background, it is found that there are several local energy enhancements which only appear in Boso area. Especially during the 2002 and the 2007 slow slip events, significant anomalous behaviors have been detected in both Y and Z components. Time series of magnetic signals associated with this two slip events are quite similar. To verify these phenomena and clarify possible mechanism, direction finding and numerical simulation have been applied and detailed results will be presented in our presentation.

Keywords: ULF seismo-magnetic phenomena, Slow slip events, Wavelet transform, Principal component analysis (PCA)

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SCG058-P02 Room:Convention Hall Time:May 23 10:30-13:00

The discovery of deep tremor and low-frequency earthquakes in Kyushu, Japan

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Kyushu is a part of the Nankai-Kyushu-Ryukyu subduction zone where the Philippine Sea plate is subducting beneath the Eurasian plate. In this area, tectonic tremors and low-frequency earthquakes (LFEs) have not been discovered yet, though they are well-studied in Tokai, Kii, and Shikoku Regions along the Nankai subduction zone. The subducting plate beneath Kyushu is a little older, but there is a high Vp/Vs zone at around 30 km depth, which is considered as an essential structural feature for tremor generation (Matsubara et al., 2009).

The envelope correlation method of Ide et al. (2010) detected many tremor activities including LFEs beneath Kyushu, in northern and southern Miyazaki prefecture. The waveforms have the characteristics of LFEs, such as dominant frequency range (1-10 Hz), detectable S-wave arrivals and obscure P-waves, and successive occurrence, similarly to those observed in the Nankai subduction zone. We relocated these LFEs, using manually identified S-waves in band-passed waveforms between 2-8 Hz, and S-P times measured by cross-correlating waveform envelopes between vertical and horizontal components. For each LFE, S-waves constrain the epicenter and S-P times at stations near the epicenter constrain the depth.

The depths of LFEs are distributed between 30 and 50 km, which are shallower than the depths of intraslab earthquakes in this area, which are between 50 and 60 km. The locations of LFEs suggest that they occur on the interface between Eurasian plate and Philippine Sea plate, and also at the depth of known high Vp/Vs area, which suggests the presence of fluid. The two areas of active LFEs are located on the northern and southern edges of the subducting Kushu-Palau Ridge. Although the distribution is not continuous like LFEs in the Nankai subduction zone, the above findings suggest that similar phenomena are occurring beneath Kyushu. The existence of slow-slip events may be predicted.

Keywords: deep tremor, low frequency earthquake, Kyushu, envelope correlation

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SCG058-P03 Room:Convention Hall Time:May 23 10:30-13:00

Non-volcanic low frequency tremors only detected by vertical seismic array network (V-net)

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In 2007, Geological Survey of Japan, AIST has started an integrated borehole observation in southwest Japan for forecasting the anticipated Tokai, Tonankai and Nankai megathrust earthquakes. Each observatory has three boreholes with different depths (about 30 m, 200 m and 600 m), in which we installed high-sensitivity seismometers at the bottom of every borehole. On the basis of a semblance analysis using this vertical seismic array network (V-net) data, we developed a monitoring system of the Non-volcanic low frequency tremors (LFTs) and showed a dramatic improvement of the LFTs detection (Takeda et al., 2010). In this study, we report the LFTs activities that were only detected by using the V-net seismograms and investigate their features.

The LFTs activities generally last for days to week in southwest Japan and occur repeatedly with a recurrence interval for three to six months (e.g. Obara 2010). These LFTs activities are easily recognized with an envelope correlation method (ECM) or on an earthquake catalogue reported by Japan Meteorological Agency (JMA). We call these activities ”a major episode”. In this study, we found many other LFTs activities that were detected by a semblance analysis using the V-net seismograms (vertical seismic array detection method; VSAD) during the V-net observation over the last two and a half years. Durations of these activities had almost equivalent to those of major episodes, and some of them lasted over one week. It should be noted that most of these activities could not be detected by ECM and were not listed in the JMA catalogue. It means that seismic radiation energies of these activities are extremely smaller than those of major episodes.

It is difficult to determine the LFTs location by using the VSAD method. However, some of these activities were simultaneously detected by multi-observatories, and then we could roughly estimate their locations. Our result suggests that some of these LFTs episodes occur in a gap region of LFTs activity.

References:

Obara K. (2010), Phenomenology of deep slow earthquake family in southwest Japan: Spatiotemporal characteristics and segmentation. J. Geophys. Res., vol. 115, B00A25.

Takeda N., K. Imanishi, and N. Koizumi (2010), Precise Monitoring of Non-volcanic Low-frequency Tremors using Vertical Seismic Array: The case of Tokai Area, Southwest Japan. 2010 AGU fall meeting.

Keywords: Non-volcanic low frequency tremors, vertical seismic array, semblance analysis, V-net, VSAD

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Observation of deep low-frequency earthquakes (LFE) using a middle scale array at Shimoyama in Toyota city, Tokai

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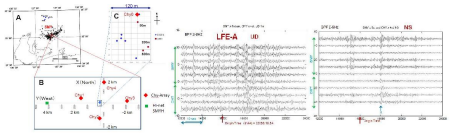
Tono Research Institute of Earthquake Science (TRIES) installed a small scale array at Shimoyama in Tokai area in 2006 (Figure A and C). This array (SMY) has 6 high-sensitive seismographs (2Hz) with three components in a square area with about 120 m sides. On March of 2010 we also installed a middle scale array in about 3 km x 3km square at Shimoyama (Figure B). This array (CHY) started observation by using 4 stations of Chy 1-4. And Chy0 station started from December 2010 (Figure c).

All of the seismic stations of CHY array have three-component seismographs (JEP-6B3, 0.1-10Hz) of acceleration type at the depth of 4 m. By using the data-logger of LS7000 we digitize their signals. Their digital sampling rate is 200 Hz. The digitized data are transported to the data center of TRIES by using the lines of ADSL, ISDN, and mobile phone.

We observed a remarkable activity of LFE occurring in Tokai area from 11 to 30, November in 2010 by both of SMY and CHY arrays. Those epicenters which were located by JMA (Japan Meteorological Agency) are shown in Figure A. SMY and CHY arrays locate in the region of the epicenters. Most of the seismic waves of LFE's recorded by the stations of the arrays show complicated as like as noise or tremor. An example of one minute length records of a LFE which we call LFE-A tentatively is shown in the figure. The JMA hypocenter of LFE-A is as the following:

2010/11/13, 23h58m19.54s, N35.014, E137.294, Depth36.1km, M0.6

The coherence of the seismic waves among data channels of SMY array is good not only in NS component but also UD component. But the coherence of CHY array is slightly good in NS component but poor in UD component. Using the records of SMY and CHY arrays we will research azimuths and apparent velocities of seismic waves propagating from LFE sources.



Keywords: deep low-frequency earthquakes, middle scale array, acceleration type seismometer, activity in Tokai district, Shimoyama in Toyota city, seismic observation

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SCG058-P05 Room:Convention Hall Time:May 23 10:30-13:00

Activity of non-volcanic tremors associated with the 2009-2010 slow slip event in the Bungo Channel region

Tsuyoshi Kishimoto[1*], Naoki Suda[1], Shinzaburo Ozawa[2], Hiroshi Yarai[2]

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In the Bungo Channel region, the westernmost region of tremor belt in southwest Japan, tremor episode energetically occur with a recurrence interval of 2 to 3 months. Long-term slow slip events occurred in 1997, 2003, and 2009-2010 at the shallower portion of the subducting plate interface in the same region. It has been shown that these aseismic slips activated tremor occurrences. Recently it has been observed that very low-frequency earthquakes are also associated with these events at the further shallower portion near the trench axis. This indicates that long-term slow slip events modulate the occurrences of other slow earthquakes. In this study, we have investigated characteristics of the space and time variation in seismic moment release due to tremors in the Bungo Channel region before and during the 2009-2010 slow slip event for elucidating relation between tremor and slow slip.

Keywords: slow slip event, non-volcanic tremor, Bungo Channel, slow earthquake, reduced displacement

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Repeating slow slip events in the Hyuga-nada and off the Tanegashima Island

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[1]GSI of Japan

GPS network of the Geospatial Information Authority of Japan has detected several slow slip events in southwestern Japan. In the Bungo channel between Shikoku and Kyush Islands, slow slip events have been detected with over one year duration in 1997, 2003, and 2009-2010. In Hyuadana area, the Pacific coastal area in central Kyushu, slow slip events started with two years recurrence interval and approximately one year duration from 2004 (Yarai and Ozawa 2010). Besides, GPS sites in Tanegashima Island show transient motion after the 1996 earthquake with one year duration. The Meteorological Research Institute of Japan discovered slow slip events adjacent to the Bungo channel slow slip area. These slow slips distribute parallel to the trench, suggesting segmentation along trench axis. In this research, we investigate slow slip events using two large plate boundary models. On model covers Tanegashima, Hyuga-nada, and Bungo channel and the other plate model covers Bungo channel, Shikoku, and the Kii peninsula.

We will continue modeling by scrutinizing time series and changing the inversion condition.

Keywords: GPS, Hyuga-nada, Tanegashima, Long term SSE

Japan Geoscience Union Meeting 2011
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SCG058-P07 Room:Convention Hall Time:May 23 10:30-13:00

Long-term slow slip event around Kochi between 1978 and 1980

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Leveling and sea level data for the period from 1971 to 2010 in Shikoku, southwestern Japan, were investigated to characterize vertical deformation patterns. We estimated the steady deformation rate at each GEONET GPS station by averaging the daily coordinates for the periods from April 1998 to April 2002, and between April 2004 and April 2008, avoiding the period of the long-term SSEs.

First-order leveling surveys have been conducted repeatedly every several years since the 1970s. We determined crustal displacements by comparing leveling data from successive surveys. We subtracted subduction-related steady component derived by the GPS from the distribution of vertical crustal displacements during periods between leveling surveys. If any episodic events have not occurred, they should show little spatial variation around zero vertical displacement. However, the residual data clearly show uplift on the southwestern Shikoku coastal area for all periods, suggesting the long-term slow slip events in Bungo Channel. In addition, uplift around Kochi city between 1979 and 1982 is seen.

We used monthly mean sea level data from the Kochi, Kure, Komatsushima and Hosojima tidal stations. The monthly data were corrected for atmospheric pressures using the theoretical coefficient of 1 cm/hPa according to monthly samples measured at the meteorological observatory closest to each tidal station. We assumed that the difference between the meteorologically corrected sea levels for pairs of stations represents relative vertical crustal displacement. The pairs we used were Kochi and Komatsushima, Kochi and Hosojima, Kure and Komatsushima, and Kure and Hosojima. We can see relative upheaval approximately 10 cm at Kochi, and several to 10 cm at Kure between 1978 and 1980. This relative change is consistent with an upheaval near Kochi deduced from the leveling data. This may be a long-term slow slip on the plate interface.

Keywords: long-term slow slip, sea level, leveling, vertical crustal movement, Shikoku

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Short-term slow slip events in western Aichi Prefecture

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[1]AFERC, GSJ, AIST

Active Fault and Earthquake Research Center, Geological Survey of Japan, AIST has a network composed of about 50 groundwater observation stations in and around the Tokai, Kinki and Shikoku areas in Japan. At these stations, groundwater levels are observed. At about half of the stations, crustal strains and seismograms are also observed by the borehole strainmeters and seismometers.

It is well known that the episodic short-term slow slip events (SSE) accompanied by deep low-frequency tremors on the plate boundary along Nankai Trough. On the other hand, around northern Ise bay, tremors are less active and the short-term SSEs are also seldom observed except the event in January 2006.

Based on semblance analysis by vertical seismic array network (V-net), we searched the crustal strain changes at TYE and TYS stations in Aichi Prefecture. In March 2010 and September 2010, the short-term SSEs were observed at western Aichi Prefecture, where is located on the northeastern side of the Ise bay. In the cases, tremors were not so active.

Keywords: crustal strain change, short-term slow slip, deep low-frequency tremor, vertical seismic array, Ise bay, Nankai Trough

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Ground deformations observed at around the active area of low frequency earthquakes in Kii Peninsula

Kensuke Onoue[2*], Yoshinobu Hoso[1], Fumio Ohya[2], Wataru Morii[1], Yasuyoshi Fujita[1]

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It has been reported lately that an activity of deep low frequency earthquakes occurred in southwestern Japan many times. Characteristic tilting motions synchronized with an activity of low frequency earthquakes and short term slow slip events in many regions were reported by analyzed data of tilt-meters attached to Hi-net by Natural Research Institute for Earth Science and Disaster Prevention. Same results by analyzing data of borehole strain-meters at Tokai region and others were reported by Japan Meteorological agency. It was known that active zone of deep low frequency earthquakes was formed along north-east and south-west direction through central Mie, south Nara and central Wakayama Prefectures in Kii Peninsula. We have carried out continuous observations of ground deformations at three observation sites, that is, Donzurubo site(135.67E,34.53N), Kishu site(135.89E,33.76N) and Nakaheji site(135.64E,33.83N) closed to active zone of deep low frequency at Kii Peninsula. Ground deformations tend to be affected by meteorological condition caused by horizontal vaults with shallow depth from ground surface compare with borehole strain-meters. However, we could find the strain changes synchronized with activity of low frequency earthquakes and short term slow slip events into the records of three sites. As one of them, we obtained strain changes synchronized with activity of low frequency earthquakes of source distance with 30˜40km from November 12, 2010 for 3 days at Kishu site. At Donzurubo site of souce distance with about 70km, strain changes indicated slow and long period of about 10 days. It will be suggested that a short term slow slip event happened in this area. We examined strain changes related to activity of low frequency earthquakes about past records of these sites.

Keywords: ground deformtion, strain, Kii peninsula, low frequency earthquake, souce distance, strain-meter

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Long-period events observed by DONET

Masaru Nakano[1*], Eiichiro Araki[1], Takeshi Nakamura[1], Yoshiyuki Kaneda[1]

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Off the Kii-peninsula, Dense Observation Network for Earthquake and Tsunami (DONET) has been developed by Japan Agency for Marine-Earth Science and Technology (JAMSTEC). DONET is a network of ocean-bottom seismic stations, aiming at improving detection capability and earlier detection of earthquakes and tsunamis in this region. Each DONET station uses a broad-band seismometer (Guralp CMG-3T), a strong-motion seismometer (Metrozet TSA-100S), a hydrophone (High Tech inc. HTI-99-DY), a differential pressure gauge (product of Nichiyu-giken inc.), and a quartz pressure gauge (product of Proscientific inc.). A combination of these sensors realizes broad-band and wide-dynamic range observations in ground motion and pressure change. Data from these stations are transmitted in real-time to our laboratory through ocean-bottom optical cable. We have already installed 8stations by January, 2011.

Around the Kii peninsula and Kumano fore-arc basin, several kinds of characteristic seismic activities are known as the non-volcanic tremor (NVT) and very-low-frequency (VLF) earthquakes. Since DONET stations are deployed immediately above the source region of the VLF earthquakes, we expect that DONET data will contribute to clarify their mechanism, although any signals from these events have not yet been identified. On the other hand, we found long-period signals with dominant periods of several tens of seconds to ten minutes in the records. These signals are clearly different from the well-known signals from the NVT or the VLF earthquakes. In this study, we introduce the long-period signals observed by DONET.

One type of the long-period signals, which is most frequently observed, shows a harmonic oscillation that monotonously decays with a characteristic period of about 60 s. This signal is dominated by horizontal motion, and the particle motion is almost linear. The duration of this signal is typically between 5 and 10 minutes. Some exceptional events continued about one hour. Such a harmonic oscillation is widely observed below volcanoes. No magmatic volcano is known around Kumano fore-arc basin, although. We also found other types of signals: One is a spindle-shaped signal which oscillates with characteristic frequencies of about ten seconds. The other example shows a waveform similar to a cycloid-function, repeating at a period of about 5 to 10 minutes. Since these signals are clearly observed at single station, we could not quantitatively determine the source location or the mechanism. The fact that the signal is recorded at only one station may indicate that the source is located close to the station. A mud volcano is located in this region. We speculate these signals are originated from the mud volcano. Since only a little is known about a mud volcano, investigations of these signals may help to understand the dynamics of it.

We also can not rule out the possibility that these signals are originated from artificial sources at present. The seismometer package of DONET stations are finally buried under the ground covering with a pile of sand. The station which observed these peculiar signals is not yet completely buried. These signals might be oscillations of the sensor package caused by ocean-bottom current. This possibility can be checked after burying the sensor package. If this is the case, ocean-bottom broad-band seismic sensors should be completely buried under the ground in order to minimize artificial signals caused by ocean-bottom current.

Keywords: Mud volcano, low-frequency earthquakes

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Moment tensor inverion of broad-band ocean bottom records from very-low-frequency earthquakes off Kii peninsula (2)

Taro Okamoto[1*], Takeshi Nakamura[2], Hiroko Sugioka[2], Yasushi Ishihara[2], Aki Ito[2], Koichiro Obana[2], Shuichi Kodaira[2], Daisuke Suetsugu[2], Masataka Kinoshita[2], Yoshio Fukao[2]

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We installed three broadband ocean bottom seismometers (BBOBSs) from July 2008 to October 2009 off Kii peninsula, Japan (Sugioka et al., in preparation): in the study area activities of the very low frequency (VLF) earthquakes have been reported (Ishihara, 2003; Obara and Ito, 2005). Our BBOBSs successfully recorded VLF swarms re-activated after five years of quiescence at very short epicentral distances. During the last SSJ Fall meeting (2010) we reported the preliminary results of the waveform inversions of the VLF events. Here we report the updated moment tensors, source time functions, and waveform-relocated source positions determined by using a new structural model.

We compute the synthetic waveforms by a 2.5D finite difference method (Okamoto, 2002) because the BBOBSs were installed on the ocean bottom that is an irregular solid-fluid interface, and because the data were recorded very close to the VLF sources: approximations with flat-layered structure or with far-field terms should be avoided. In this report, we assume a ”new” crustal model based on the results of detailed seismic experiments performed in the source area: we incorporate oceanic layer, sedimentary layers, and subducting oceanic crust in the new model. Assuming a point source for the VLF source, we infer the moment tensor and the source time function simultaneously by using a non-linear waveform inversion method (Okamoto and Takenaka, 2009). Finally we apply the waveform-relocation procedure (Okamoto, 1994; Okamoto and Takenaka, 2009) to determine the best point source position: in the procedure we setup a three-dimensional grid of candidate source positions, and apply a grid search to find the best source position that minimize the residual between the observed and synthetic waveforms. The data used for the inversion are the waveforms of three components of ground velocity with durations of 120-150 s from the onset. We apply a band-pass filter (8-50s) to the raw data. For some data we also generated waveforms by applying another band-pass filter with very long period (50-360s).

We analysed eleven VLF events whose moment magnitudes were about four. We found that most (nine) of the events had shallow angle thrusting mechanism. The estimated depths of the nine events were in the range between 6.4 km to 8.4 km. Moreover, five events had very shallow, near horizontal nodal plane (i.e., dip angles were less than 10 degrees). These results strongly suggest that the shallow angle thrusting events represent the slips along the very shallow part of the plate boundary under the accretionary prism. The estimated durations of the source time functions (30-50 s or longer) of the VLF earthquqkes are much longer than the typical values for M4 events.

Acknowledgments: This research was partially supported by KAKENHI (19GS0211). The computers in Earthquake and Volcano Information Center, Earthquake Research Institute, University of Tokyo was used for FDM computations.

Keywords: VLF earthquake, Off Kii Peninsula, moment tensor, crustal deformation, finite-difference method

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Very low frequency tremors beneath Shonai plain revealed by Hi-net tiltmeters

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Monitoring of wave field in the frequency band from 0.05 to 0.2 Hz exhibits activities of very low frequency earthquakes (e.g. Ito et al., 2007) and those of volcanic tremors at Aso volcano (e.g. Kaneshima et al. 1996). In this study we showed new observation of very low frequency tremors beneath Shonai plain.

We analyzed records of Hi-net tiltmeters at about 700 stations from 2004/6 to 2006/6. At first we divided the stations into 6 sub-arrays, and we calculated wavenumber-frequency spectra at 0.075 Hz. The spectra and root mean squared amplitudes of each station suggest that activity of very low frequency tremors beneath Shonai plain at 2004/12/7. The spectra also show dominance of Love waves.

We estimated a source location for a time segment in Tohoku region by grid search as follows: (1) We divided whole records into segments of 1024 s. (2) With an assumption of 1-D structure (Nishida et al. 2008), we calculated synthetic Love and Rayleigh wave excited at an assumed hypocenter. (2) For each time segment, we calculated variance reduction (VR) between the synthetic wave fields and observed records within a 200-km radius of the assumed hypocenter. (3) We calculated VR of Love and that of Rayleigh, and we averaged them from 0.05 to 0.1 Hz.(4) We regarded the minimum of VR as the resultant hypocenter for the segment.

In most periods, the hypocenters were located along coastal regions, which correspond to source of microseisms (high activity regions of ocean swells). The results also show activities of very low frequency tremors beneath Shonai plain. The tremors with duration of several days occurred 3-4 times per a month. The hypocenters were located at a point within an error of about 5 km. Dominance of surface waves suggests that the hypocenters should be shallower than 10 km. Throughout the activities Love wave amplitudes were much larger than those of Rayleigh waves. The observed results suggest that the sources may be related to volcanic activities of Mt. Chokai, but the origin is still unknown.

Keywords: low frequency tremors