SSS27-01 Room:201B Time:May 22 09:00-09:15

High-frequency seismogram envelope synthesis of early aftershock sequences

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The detection of early aftershocks is challenging because their waveforms are hidden by the large amplitude of coda waves of the mainshock and are obscured due to the occurrence of a large number of events in a short time interval. The lack of early aftershocks in an earthquake catalog could bias the analysis and modeling of aftershock activity. In order to investigate the excitation of early aftershocks quantitatively, it is better to regard the early aftershock sequence as a continuous energy radiation process rather than discrete earthquake occurrence. In this study, we theoretically synthesize envelopes of 1-16 Hz seismograms by convolving the energy of coda waves excited by an impulsive source with the energy radiation function of an aftershock sequence. The radiative transfer theory, which accounts for the spatio-temporal distribution of the multiply scattered wave energy, is used to describe the coda excitation process. The scattering coefficient and the intrinsic absorption factor used in this theory are independently estimated from the coda wave of small earthquakes. The Omori-Utsu law, the Gutenberg-Richter law, and an omega-square source spectrum are used to describe the energy radiation function. The p- and c-values of the Omori-Utsu law and the b-value of the Gutenberg-Richter law are chosen based on results reported in the literature.

When the seismogram of an Mw7 mainshock is observed at hypocentral distances of 10-30 km, our theoretical modeling shows that the energy of scattered waves dominates over the energy excited by the early aftershocks in the first 30-100 s after the mainshock. At this lapse-time range, the envelope amplitude decays exponentially according to the functional form of the radiative transfer equation. The envelope amplitude increases as the dominant frequency decreases because the lower frequency energy is effectively excited for larger earthquakes and the attenuation of coda wave is slower at lower frequencies. On the other hand, the energy excited by early aftershocks becomes dominant after 30-100 s after the mainshock. At these later times, the envelope amplitude decays as a power-law due to the functional form of the Omori-Utsu law. Since smaller aftershocks occur more often than larger ones according to the Gutenberg-Richter law, the amount of the higher frequency component of the seismogram envelope with respect to the lower frequency counterpart increases at later times. These theoretical characteristics are confirmed by the analysis of the continuous waveforms of the 2008 Mw6.9 Iwate-Miyagi earthquake and its early aftershocks recorded by Hi-net stations.

Keywords: early aftershocks, seismogram envelope, high frequency, coda wave, Omori-Utsu law, Gutenberg-Richter law

SSS27-02 Room:201B Time:May 22 09:15-09:30

Detection of immediate aftershocks using seismogram envelopes as templates

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Hypoceneter location and its temporal variation of aftershocks are the source of information of mainshock rupture and stress perturbation around the fault. Since the number of aftershocks decays exponentially, study of immediate aftershocks is important to get the above information. However, the location of immediate aftershocks is difficult due to coda wave of mainshock and successive occurrence of afterrshocks.

Here we propose a new method of hypocenter location using seismogram envelopes as templates. There has been proposed some location methods using aftershock seismograms as templates. Our method employs envelope that are the logarithm of root-mean-squared (RMS) amplitude of band-pass filtered seismogram. The envelope is smoother and more stable than seismogram, and it changes absolute value with the earthquake magnitude but keeps its shape, which is the advantage of the use of envelope.

The proposed method composes of two processes. The first process is the calculation of cross-correlation coefficients between a continuous (target) envelope and template envelopes. Assuming an origin time, we set time windows in the target and templates to calculate the cross-correlation by referring to the arrival times of P-wave of template events. We define the average cross-correlation among the stations and three components as the cross-correlation for each template. We repeat this process by shifting the origin time to obtain a set of cross-correlation values for pairs of (origin time, template).

The second process is the event detection and location. First, we search for the maximum cross-correlation among all pairs of (origin time, template), which gives the origin time of the first event and corresponding template. At present, we simply regard template location as the location of the detected event. Magnitude of event is calculated by the amplitude ratio of target and template envelope. To avoid duplicate detection around this event, we set a dead time of detection around the origin time of the first event. Then we search for the second highest cross correlation value in a time window excluding the dead time. We repeat this procedure until the highest cross-correlation value falls below a threshold.

We applied this method to a data set of the 2004 Mid-Niigata Prefecture (Niigata-Chuetsu) Earthquake (M = 6.8) in central Japan. Aftershock activity of this earthquake is extensive with a number of aftershocks with magnitude greater than 6.0, and with a complex fault system that consists of two parallel westward-dipping faults and a conjugate fault plane. We tested the method by using target envelopes of two stations, 34 templates with a length of 8 s, both in a center frequency of 4 Hz. During a period of one-hour from the mainshock, we could detect 71 events, which are comparable to the number of the catalog events. The location of events are generally near the catalog location, however, the event magnitude is systematically larger than the catalog value. Of course the result depends on the above parameters and we should develop a method of suitable selection of parameters. In addition, we should improve the method of magnitude estimates and, most importantly, relative location of events against templates. Though we have much job to do, we conclude that the employment of envelopes as template works adequately even just after the mainshock of large inland earthquake.

Acknowledgement: We used hypocentral parameters and arrival time data of the JMA catalog that was prepared by the JMA and the Ministry of Education, Culture, Sports, Science and Technology in Japan. I thank the National Research Institute for Earth Science and Disaster Prevention (NIED) and the University of Tokyo for providing waveform data. This work was supported by JSPS KAKENHI Grant Number 23540487.

Keywords: aftershocks, hypocenter location, template, envelope, correlation, Chuetsu earthquake

SSS27-03 Room:201B Time:May 22 09:30-09:45

Estimation of faulting types of small earthquakes using template events east off Tohoku

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In the northeastern Japan subduction zone, there are many earthquakes with various focal mechanisms. The most reliable focal mechanisms are those evaluated using CMT solutions, but it is difficult to estimate CMT of small earthquakes. However, it is essential to know focal mechanisms of small earthquakes to discuss earthquake generation process in detail.

In this study, we have developed a new method that classifies small earthquakes into several groups of faulting types. In the method, we used template events whose focal mechanisms are known. For pairs of target and template events, we evaluated the similarities of the waveforms for several stations. If the two events are located at the same location and have the same focal mechanism, they should show very similar waveforms at the same station. Thus if the cross-correlation coefficients are large for two events, we can consider the two events have similar focal mechanisms. As a first step, we examined relationship between the focal mechanism differences and the waveform cross-correlation coefficients whose focal mechanisms are known. Here, the differences in focal mechanisms were quantified by using minimum 3D rotation angle (Kagan, 1991). The P and S waves were separately analyzed by using 10 second time windows to reduce the effect of the separation distance between the two earthquakes. Although there were many event pairs with low cross-correlation coefficients for event pairs with small differences in the focal mechanisms, we found that event pairs with large cross-correlation coefficients (CC) always had small differences in focal mechanisms and small inter-event distances. According to the evaluation of the focal mechanism-known pairs, we adopted a threshold of CC>=0.6 to select events with similar focal mechanisms.

As a second step, we calculated CC of event pairs; in each event pair, the focal mechanism of one event (template event) is known but the other (target event) is not. We classified events using the threshold of CC>=0.6. Most events were classified as thrust faulting and some events were normal faulting.

Although we need more effort to optimize the method, our method based on template events has a potential of classifying large number of earthquakes into several fault types.

Keywords: focal mechanism, template event, subduction zone

SSS27-04 Room:201B Time:May 22 09:45-10:00

Small repeating earthquakes after the 2011 off the Pacific coast of Tohoku earthquake (2)

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The 2011 off the Pacific coast of Tohoku earthquake (Mw9.0) was the largest earthquake in recorded history in Japan. For the stress changes by this earthquake, many aftershocks and induced earthquakes have occurred in and around the source regions. In this study, I show the space-time characteristics of the inter-plate aseismic slip from sequences of small repeating earthquakes in Japan after the 2011 Tohoku earthquake.

I have already detected many small repeating earthquakes occurred at the upper boundary of the subducting plates in Japan before the 2011 Tohoku earthquake. The inter-plate slip-rates estimated from these sequences were consistent to the space-time changes of the inter-plate coupling. I also identified aseismic slips following large inter-plate earthquakes occurred in 2003 to 2008 and quasi-static slips associated with foreshocks off Miyagi that started from 2011.

After the 2011 Tohoku earthquake, seismic activities of small repeating earthquakes become active around the source regions. They are particularly active in the northwestern deeper part of the 2011 main-shock and its large aftershocks. The cumulative slip is more than 4 m in the most frequent area and is consistent to the value estimated from GPS data analysis. Detected sequences also show post-seismic slips at the trench-side of the northern and southern part of the source region in the subducting Pacific plate and in the subducting Philippine Sea plate beneath the metropolitan district, which suggest induced inter-plate slips. In two years after the earthquake, the slip-rates are three to five times of the relative plate motion in the north and western part. On the other hand, they are almost decreasing to the rate before the 2011 main-shock in the southern part. I cannot detect small repeating earthquakes within coseismic slip areas of the 2011 main-shock and large aftershocks after the 2011 main-shock. Distributions of small repeating earthquakes probably outline their large slip areas. Therefore, I suggest that both coseismic slip areas and after-slip areas of large earthquakes can estimate from the space-time changes of small repeating earthquakes.

Some of small repeating earthquakes are burst-type sequences which occur only after the 2011 Tohoku earthquake. Observed seismograms may be distorted by the multiplicity of the seismic waves to come from various places, the seismic velocity changes at the propagation path or site, or changes of physical properties at the plate interface. Other repeating sequences, which classify in continuous type conventionally and are not detected after the 2011 main-shock, seem to be included in earthquake clusters influenced for the recurrence cycle of the larger earthquake. We should pay attention to future activities to investigate whether physical property at the plate interface has changed by the effect of inter-plate large slip and stress changes.

Keywords: The 2011 off the Pacific coast of Tohoku earthquake, small repeating earthquake

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SSS27-05 Room:201B Time:May 22 10:00-10:15

The great 1933 Sanriku-oki outer-rise earthquake: Relocated aftershocks, recent seismicity and fault scarp morphology

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The 1933 Sanriku-oki earthquake is the largest earthquake that occurred outer trench-slope region of the northern Honshu, Japan. Recent observations and analyses on earthquakes, such as 2006 and 2007 Kuril earthquakes, 2004 Sumatra earthquake suggest the interactions between outer-rise and interplate thrust earthquakes. Thus it is important to examine the mechanisms of the aftershocks of the 1933 earthquake that encompass a wide area including the inner trench region according to the JMA location. In this study, we examined the data quality of the 1933 earthquake based on smoked paper records and relocated the earthquakes by using phase data from regional stations and modern relocation methods. Relocations by the double-difference method show about 170 km long aftershock area under the outer trench slope that is separated from the seismicity under the inner trench slope. The earthquakes under the inner trench slope were located where recent activity of interplate thrust earthquakes is high. Separation of aftershock activity between outer trench-slope and inner trench slope was also confirmed by a examination of recent earthquakes that are accurately located based on OBS data at the study area. Earthquakes under the inner trench slope immediately after the 1933 Sanriku-oki earthquake are consistent with earthquake location discrimination based on waveforms and S-P time data (Umino et al. 2007). These two regions of seismicity suggest stress triggering of interplate earthquakes by the deformation from the 1933 outer-rise earthquake. We also relocated pre March 11th, 2011 seismicity near the trench region. The result show the present seismicity at the outer trench-slope region of northern Honshu can be divided into several groups of earthquakes along the trench; one group roughly corresponds to the aftershock region of the 1933 earthquake. Comparison of the 1933 rupture dimension based on our relocations with the morphologies of fault scarps in the outer trench slope suggest that the rupture was limited by the region where fault scarps are trench parallel and cross cutting seafloor spreading fabric.

Acknowledgements: We thank R. Hino and K. Obana for providing relocated hypocenter of earthquakes based on OBS data, Y. Tamura for access to seismograms of the 1933 earthquake and its aftershocks recorded at the Mizusawa observatory and JMA for phase data of earthquakes.

Keywords: 1933 Sanriku-oki earthquake, outer-rise earthquake

SSS27-06 Room:201B Time:May 22 10:15-10:30

An approximately-nine-year-period variation in seismicity and crustal deformation near the Japan Trench

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It is well known that the statistical probability of earthquake occurrences changes over the course of a day due to periodic variations in the tidal stress acting on faults. However, periodicity on a decadal scale has been studied by relatively few people. It has been reported that approximated ten-year periodicity is observed globally for the seismicity of M-8-class large earthquakes. However, the mechanism underlying this periodicity has not yet been revealed. In this study, decadal-scale periodicity of earthquakes along the Japan Trench is investigated. A new finding is presented that in northeast Japan, since 1923, the probability of the occurrence of earthquakes with an M $>=5$ has increased approximately every nine years. This increase in probability is also evident for historic events with an M$>=6$ that occurred during the past one thousand years, implying the presence of a periodic stress disturbance at an appreciably regular interval. Periodicity becomes even more apparent for large earthquakes with an M>7.5 and about half of the recorded 29 events intensively occurred within two successive years on a cycle of approximately nine years. The past strain and tilt observations conducted in Japan during the 1950s through the 1970s indicate that nation-wide gradual compression was repeating every 8–10 years in the direction of relative plate motion. These compression periods are in accordance with the periods of higher seismic activity discussed above. As a first step in investigating the origin of earthquake periodicity, periods associated with lunar motion are considered. It is shown that a long-term motion primarily governed by the period of the lunar perigee is synchronised with the cyclic variation in seismicity and crustal deformation described above. Decadal changes in tidal stress, as calculated using an ordinary theory of solid Earth tide, are too small to cause periodic variations in seismicity. Therefore, the conditions by which tidal stress is sufficiently amplified to trigger an earthquake are investigated. The results show that, if assuming that a tidal force acts on a spherically asymmetric block-like upper mantle beneath the Pacific Plate, the computed phase and amplitude can explain the observations. Otherwise, it is difficult to consider direct tidal force alone as the main source of periodic variations in seismicity. Other possibilities should be considered, such as unknown interactions between the plate boundary and the ocean/atmosphere with a period of around nine years or a resonance between the period of the tidal force and a recurrence period of slow slip events in the transition zone on the plate boundary. Apart from understanding the origin, the important fact confirmed in this study is that in some areas, the occurrence of large earthquakes, if considered as a group, appears to be strongly governed by a periodic stress disturbance rather than by completely random processes. Elucidating the wide-range approximated nine-year mode helps us narrow a range in occurrence time in a probabilistic mid-term prediction of large interplate earthquakes.

Keywords: crustal deformation, earthquake cycle, seismicity, tide, subduction zone

SSS27-07 Room:201B Time:May 22 10:30-10:45

Pseudo earthquake quiescence following the 2011 M9.0 Tohoku-Oki earthquake

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The large extensional stress perturbations associated with the 11 March 2011 Tohoku-Oki earthquake (magnitude (M) 9.0) [e.g., Ozawa et al., 2011] has boosted widespread increase in seismicity across NE and central Japan [e.g., Kato et al., 2011; Toda et al., 2011; Miyazawa, 2012]. In addition to the induced seismicity, several sequences of earthquake quiescence or sudden reductions of seismicity were reported after the Tohoku-Oki earthquake [e.g., Toda et al., 2011]. However, it has been argued that sudden rate reductions were potentially due to temporal changes in the completeness magnitude threshold of any earthquake catalogue following the immediate aftermath of large mainshock [e.g., Felzer and Brodsky, 2005; Peng and Zhao, 2009]. After the Tohoku mainshock, small magnitude earthquakes tended to be masked by overlapping arrivals of waves from immediately following numerous earthquakes occurred in not only the source region of the Tohoku mainshock but also inland regions.

For example, a seismic cluster broke out on 27 February 2011 in the Hida mountain range (near Norikura), where the present volcanic front is located, and its activity had continued until the Tohoku-Oki mainshock. The representative focal mechanisms are thrust and strike-slip faulting with the P-axis aligned WN-SE direction, which is a typical stress field in this region. Just following the Tohoku mainshock, the seismic activity reported in the JMA catalogue shows earthquake quiescence: one day later the seismicity gradually turned around its previous level. In order to investigate whether this earthquake quiescence is real or not, we applied a matched-filter technique to detect missing events with the use of continuous three-component velocity seismograms recorded by a dense network of continuous and highly-sensitive seismic stations.

In contrast to the JMA catalogue, the seismicity in the cluster has still continued even just after the Tohoku mainshock and seismic quiescence was not observed. We identified a total of several tens of events in the cluster during a time-window when the JMA has not reported any existence of seismic events. Our newly detected catalogue describes the temporal and spatial evolutions of seismicity more precisely. The newly constructed catalogue in the Hida Mountain range (near Norikura) shows that the seismicity increased in the immediate aftermath of the Tohoku mainshock. This rate increase is likely explained by a static-stress transfer model. Thus, the quiescence seen in the JMA catalogue following the Tohoku mainshock is artificial due to temporal increases in the completeness magnitude threshold of the catalogue.

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS27-08 Room:201B Time:May 22 11:00-11:15

Characteristics of triggered tremor beneath the Yatsushiro Sea by the surface wave of a teleseismic event

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Chao and Obara(2012, SSJ) and Obara et al.(2012, SSJ) found tremors induced by the surface waves of the 2012 Mw8.6 Sumatra earthquake. One of the tremors occurred near the Yatsushiro Sea, the western part of the Kyushu Island. In this study, we reexamine the characteristics of the tremor by using data from the dense seismic network deployed around the sea.

We detected the locations and time evolution of tremors by a grid search method. Waveforms at the seismic stations are stacked with time shifts calculated from the location at a grid. The optimum location is determined at the grid where the power of the stacked waveform is largest among the spatially distributed. The time evolution is detected by checking the power for various origin times. We found that the tremors were located at the depth of around 20km. It corresponds to the lower limit of background seismicity.

Acknowledgement

We used the seismic data from Kyushu University, the Japan Meteorological Agency, the National Research Institute for Earth Science and Disaster Prevention and Kagoshima University.

Keywords: triggered tremor, the Yatsushiro Sea

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SSS27-09 Room:201B Time:May 22 11:15-11:30

Spatiotemporal stress change concerned with Tohoku-Oki Earthquake derived from the seismicity rate in off southern Tohok

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Using a method of Dieterich (1994), we estimated spatiotemporal evolution of Coulomb stress in and around the subducted Pacific (PAC) plate and Philippine Sea (PHS) plate in off southern Tohoku and Kanto district from the analysis of seismicity rate.

Our results show that the Tohoku-Oki Earthquake extensively perturbed Coulomb stress in the PAC and PHS plates. In a previous study, Uchida et al.,(2009) suggested that an interplate coupling between the PAC and PHS plate becomes weak in the southern part of northeastern edge of the PHS plate. In our results, however, large stress change was seen in this region during March 2011. We also found that such region showing large stress change have been moving southward for several months. After March 2011, M$>$5 earthquakes occurred near the region which had stress change in March 2011. Widespread large stress change are considered to be related to occurrence of M$>$5 earthquakes.

Next, we determined focal mechanisms of earthquakes which occurred in the study region. For some events after Tohoku-Oki Earthquake, P and T axes' direction of the focal mechanisms were different from those for the events before mainshock. The regions where mechanism trend varied before and after the Tohoku-Oki Earthquake seem to coincide with the regions where large stress change was observed.

Keywords: Tohoku earthquake, Sterss change, Aftershock

SSS27-10 Room:201B Time:May 22 11:30-11:45

Seismicity and crustal structure in the focal area of the inland earthquakes induced by the 2011 Tohoku-Oki earthquake

Tomomi Okada[1*], Ryota Takagi[1], Keisuke Yoshida[1], Maki Yonekawa[1], takuya yamamura[1], Akira Hasegawa[1], Group for the aftershock observations of the 2011 Tohoku-Oki earthquake[1]

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After the occurrence of the 2011 Tohoku earthquake with a magnitude of 9, the seismicity in the overriding plate has changed. The seismicity seems to form the seismic belts. The earthquakes after the 2011 Tohoku earthquakes tend to be located at the edge of these seismic belts.

From the time-latitude distribution, we can see the change of seismicity in the occurrence of the 2011 Tohoku earthquake. Most of the earthquake clusters have activated just the 2011 Tohoku earthquake and decreased, although some of them activated gently. In some earthquake swarms, we can observe temporal expansion of the focal area. This temporal expansion can be explained by the fluid diffusion.

In the lower crust, we found seismic low velocity zone, which seems to be elongated along N-S or NE-SW, the strike of the island arc. These seismic low-velocity zones are located not only beneath the volcanic front but also beneath the fore-arc region. Seismic activity in the upper crust tends to be high above these low-velocity zones in the lower crust. Most of the shallow earthquakes after the occurrence of the 2011 Tohoku earthquake are also located above the seismic low-velocity zone. Normal fault earthquakes in northern Ibaraki and southeastern Fukushima are also located just above the seismic low-velocity zone.

SSS27-11 Room:201B Time:May 22 11:45-12:00

Swarm Activity at the Southwestern Frank of Mt. Norikura, Gifu Prefecture, Central Japan, in February and March, 2011

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An intense swarm activity was observed around the south-western frank of the Mt. Norikura, Gifu Prefecture, Central Japan, in February and March 2011. Swarm activity took place at 2:18 JST, February 27, 2011 with a Mjma 5.0 earthquake followed by a Mjma 5.5 event at 5:38 JST, February 27, which is the largest event in this activity, The activity decreased until the end of March, with slight re-activation until the end of December 2011. Focal mechanism solutions derived from the first P-wave motion analyses exhibit the NNW-SSE compression stress field that indicates these earthquakes are located on the ENE extension of the Takayama-Oppara fault system which roughly run NE-SW direction in Hida district, Gifu Prefecture.

We applied the matched-filter technique to this seismic activity if we could detect the temporal evolution of such an intense activity quickly. We selected thirty (30) templates earthquakes recorded at surrounding nine (9) seismic stations for matched-filter detection. More than 4,800 events are detected during the period from February 27 to March 31, which is about three times as JMA located. Number of earthquakes we could locate is about one third of detected events, which is roughly same as the JMA located. Although we have to check the precision and accuracy of our located events for precise discussion, we could say this method is one of the powerful tools to investigate the temporal variations of swarm activities.

Keywords: swarm activity, Hida district, Gifu Prefecture, Mt. Norikura-dake, Takayama-Oppara Fault, matched-filter technique

SSS27-12 Room:201B Time:May 22 12:00-12:15

The relationship between shallow seismicity and geologic structure in the Sambagawa belt, northwestern Kii Peninsula

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Background seismicity is significant in both Tamba and Wakayama regions, Kinki district, southwest Japan. Although Katao and Ando (1996) and others already pointed out that the geologic structure controls their hypocenter distributions, no detail study has been performed. Here we examine the spatial relationship between seismicity and geologic structure in the Wakayama region, northwestern Kii Peninsula, analyzing the hypocenter relocations by the hypoDD method, and seeking more fault plane solutions of microearthquakes. In addition, we perform a three-dimentional comparison between deep geologic structure estimated from the Bouguer gravity anomalies and the relocated hypocenter distribution.

As a result of the hypoDD relocations, E-W trending seismic clusters have become more visible. Other trends of linear seismic clusters are also discernible. Linear and elongated seismic clusters in the western Sambagawa metamorphic belt are unconcealed. Numerous fault plane solutions sought from smaller earthquakes using the Kyoto University SATARN system increase the ratio of strike-slip mechanisms to the reverse ones, which may associate with the visible EW-trending seismic clusters. Two 20-km-long, EW-trending high gravity anomaly zones, which are robust features (Kakuta et al, 2002, Komazawa et al, 1999), is characterized as aseismic zones. These zones, evidently corresponding to the Mikabu ultramafic rocks, hold higher density than those from schist and other sedimentary units. We interpret that significant difference in mineral compositions between the Mikabu zones and the other areas in the Sambagawa belt plays an important role to differentiate their brittle-ductile transition depths, thus the thickness and strength of the seismogenic layer.

Keywords: northwestern Kii Peninsula, Sambagawa belt, shallow seismicity

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SSS27-P01 Room:Convention Hall Time:May 22 18:15-19:30

Relation between Temporal Variation of b-value and Recurring Slow Slips off Boso Peninsula: Part 2

Fuyuki Hirose[1*], Kenji Maeda[1]

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Hirose & Maeda (2012, JpGU) investigated a relation between temporal variation of b-value of the G-R law (Gutenberg and Richter, 1944, BSSA) and stress change associated with slow slip events (SSEs) around Boso peninsula. They interpreted their result as follows by considering the inverse correlation between b-value and stress obtained in laboratory experiments (Scholz, 1968, BSSA):

1) Because a coupling rate is low in the period of no SSEs in the area where swarm earthquakes occur, stresses applied to the region becomes also low. Therefore, b-value becomes large.

2) Seismicity activates at the north edge of the SSE area because stresses increase around the SSE area according to an occurrence of SSEs. In this situation, b-value decreases because of high stress.

3) After that, because SSEs converge within a week or 10 days, stresses applied to adjacent area around SSEs decrease gradually. A b-value increases gradually with decrease of stresses and has a peak value before next SSE.

They used JMA catalogue in the period of 1990/1/1 ? 2011/12/31 with M ? 1.5 and Depth ? 40 km, and relocated hypocenters by Double-difference (DD) method (Waldhauser & Ellsworth, 2000, BSSA). And they calculated temporal changes of b-value using events that may occur near plate boundary.

On the other hand, we obtained seismic waveform data after August, 2002. We will relocate hypocenters precisely using both methods of waveform cross-correlation and DD and retry to calculate temporal changes of b-value. We will report our result in the session.

Keywords: Boso peninsula, slow slip, b-value, stress, temporal change, waveform cross-correlation

SSS27-P02 Room:Convention Hall Time:May 22 18:15-19:30

Earthquake Observation in the Suruga Trough Using Ocean bottom Seismographs-Preliminary Report-

Hisatoshi Baba[1*], Kenji Hirata[2], Hiroaki Tsushima[3], Tatsuya Miyagawa[1], Tsuyoshi Matsumoto[1], Kazuya Inamura[1], Akio Katsumata[3], Hiroshi UENO[3], Shigeki Aoki[3], Kenji Maeda[3], Takashi Yokota[3], Toshiyasu Nagao[1]

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Tokai Univ. and MRI, are carrying out the single station earthquake observation near the Suruga Trough axial region, east end of a possible near-future Tokai Earthquake, using pop-up type OBSs from October, 2011 to July 2012. After the single-station observation, we are conducting tripartite observation of three OBSs. Deployment and recovering of the OBSs are repeatedly conducted every three months using small work boat with about 20 ton ages of Tokai Univ. In the Suruga Trough axial region, seismicity became active since-years ago; moderated-size earthquakes occurred there (M6.5 in 2009 and M6.1 in 2012).

Although those are believed earthquakes occurred in the subducting Philippine Sea Plate, from land network observation, depth of these moderated-size events may not be necessarily constrained well because of lack of observation within the Suruga Bay.

We report a preliminary result about single-station observation to examine local seismicity in the Suruga Trough axis in terms of frequency and S-P time distribution.

From January 2012 to July 2012, the following results were found.

(1) During this time, the single OBS observation detected 11,539 events.

(2) About 5,000 events show S-P time of less than 5sec. About 1,100 events show those of less than one second.

(3) The earthquakes with S-P time of less than one second are considered to occur in the Philippine Sea plate, not in the land plate.

By the second stage observation from August 2012, we installed OBSs in three sites around Suruga Trough. In our presentation, we would like to mention some preliminary results of the tripartite observation.

Keywords: Earthquake Observation, Suruga Trough, Ocean Bottom Seismograph

SSS27-P03 Room:Convention Hall Time:May 22 18:15-19:30

Earthquake Observation in and around Kumano Nada using Cable and Pop-Up type Ocean Bottom Seismographs

Hiroshi Sarukawa[1], Hisatoshi Baba[2*], Kenji Hirata[3], Akira Yamazaki[4], Hiroaki Tsushima[5], Akio Katsumata[5], Hiroshi UENO[5], Shigeki Aoki[5], Kenji Maeda[5], Takashi Yokota[5]

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From October, 2008, JMA started earthquake observation offshore in the middle of the Nankai Trough using cable type Ocean Bottom Seismographs (OBSs) which has been installed from the Tokai-Oki area to Kumano Nada area. Then MRI and JMA installed twelve of pop-up type OBSs around the cable type OBSs from June, 2009 to September, 2009. Aim of this campaign observation is (1) examine the hypocenter determination ability of the JMA cable type OBSs, (2) to compare hypocenter distributions determined by only the cable type OBSs or a combination of cable type + pop-up OBSs with those by land seismic networks for understanding of feature or disposition of hypocenter distributions determined by different combination of offshore and land observation. During three months of the campaign observation, a combination data set of the cable and pop-up type OBSs detected 188 events, most of which were located around Nankai Trough axis. These hypocenters depth distribution are about 20 ? 50km, but decided by only cable type OBSs are tends to become relatively shallow. Comparison of hypocenters with those determined by the land network suggests that hypocenter distribution determined by both of cable and pop-up type OBSs shows the cluster form.

In this presentation, we further discuss feature and disposition of the hypocenter distribution estimated by the cable type OBSs as well as geographical feature if seismicity in this area.

Keywords: Earthquake observation, Ocean Bottom Seismograph, Tokai Oki, Kumano Nada, Comparison of the hypocenter

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Relationship between seismicity off Awashima inferred from Ocean Bottom Cabled Seismometers and 1964 Niigata earthquake

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The Niigata-Kobe Tectonic Zone (NKTZ) (Sagiya et al., 2000) is placed in the eastern margin of the Japan Sea, many large earthquakes occurred within NKTZ (e.g. 1964 Niigata earthquake, 2004 Chuetsu earthquake, and 2007 Chuetsu-oki earthquake). To understand the generation mechanism of these earthquakes and a formation of the NKTZ, it is important to obtain detailed hypocenter distribution around the NKTZ. It is difficult to locate hypocenters in offshore regions only land seismic stations and we cannot understand seismicity around NKTZ precisely.

We have been monitoring seismic activity by using Ocean Bottom Cabled Seismometers (OBCSs) from August 2010 off Awashima which the epicenter of the 1964 event is located. A seismic survey using airgun and these OBCSs was conducted to obtain seismic velocity structures around deployment of OBCSs. The data of the OBCSs enable us a precise location of hypocenters. In this study, we determine hypocenters occurred around Awashima and discuss relationship between these events and a mainshock fault plane of 1964 Niigata earthquake.

We determined 23 hypocenters using data from OBCSs. Most of these hypocenters occurred at depths ranging from 5km to 20km. These focal depths were shallower than focal depths determined by Japan Meteorological Agency. The hypocenter by OBCS form a plane dipping to the west and the dip of plane is estimated at 34 degree. The dip angle is smaller than one of the mainshock fault plane of 1964 event. We interpret that these events do not occur on the mainshock fault plane of 1964 Niigata earthquake. We need to accumulate data from OBCSs to reveal the relationship between seismic activity around Awashima recently and the fault plane of 1964 Niigata Earthquake.

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Hypocenter distribution around the 2011 Tohoku-Oki earthquake by using Ocean Bottom Seismographic data

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A megathrust earthquake (M9.0), the 2011 off the Pacific coast of Tohoku earthquake (the 2011 Tohoku-Oki earthquake), occurred on Mar. 11, 2011 along the Japan Trench subduction zone. Its hypocenter and the area of major moment release are located in the Miyagi-Oki region, middle part of the Japan Trench area, where large interplate earthquake (~M7.5) have repeatedly occurred at about 40 years intervals. Since 2002, we have repeatedly deployed and retrieved pop-up type Ocean Bottom Seismometers (OBSs) to monitor the seismicity in the region. By using this OBS network, we could observe a sequence of the foreshocks, the mainshock and aftershocks of the 2011 Tohoku-Oki earthquake in their close vicinity.

Suzuki et al. (2012) relocated these hypocenters by using OBSs data. Although OBSs deployed in the area observed the series of earthquakes and their data provided with improved image of the hypocenter distribution, they relocated only early aftershocks occurred until 21 May 2011. In this presentation, we will report the aftershock distribution relocated by including the OBS data recovered in 2012 from the off-Miyagi region where large (> 10 m) coseismic slip occurred at the 2011 Tohoku-Oki earthquake.

The mainshock hypocenter was relocated slightly westward from that reported by Japan Meteorological Agency (JMA), placing it near the intersection between the plate boundary and the Moho of the overriding plate. The foreshock seismicity mainly occurred on the trenchward side of the mainshock hypocenter, where the Pacific slab contacts the island arc crust. The foreshocks were initially activated at the up-dip limit of the seismogenic zone ~30 km trenchward of the largest foreshock (M 7.3, two days before the mainshock). After the M-7.3 earthquake, intense interplate seismicity, accompanied by epicenters migrating toward the mainshock hypocenter, was observed. The focal depth distribution changed significantly in response to the M-9 mainshock. Earthquakes along the plate boundary were almost non-existent in the area of huge coseismic slip, whereas earthquakes off the boundary increased in numbers in both the upper and the lower plates, including intensive aftershock activities of intraplate earthquakes with magnitude more than 7.

Keywords: Tohoku-Oki earthquake, OBS, Miyagi-Oki, seismicity

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Precise aftershock distribution of the southernmost rupture area of the 2011 Tohoku-oki earthquake by OBSs

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The 2011 Tohoku-oki earthquake (MJMA = 9.0) occurred on the megathrust where the Pacific plate subducts below northern Japan arc on March 11, 2011. Many studies on slip distribution and source process of the main shock have been done, such as geodetic slip model [e.g. Ozawa et al., 2011], tsunami slip model [e.g. Fujii et al., 2011, Maeda et al., 2011], joint inversion of GPS, teleseismic, and tsunami observations [Simons et a., 2011] and rupture process [e.g. Yoshida et al., 2011]. They indicated the rupture area extends approximately 450 km in length and 200 km in width. The seismic experiment using airgun and Ocean Bottom Seismometers (OBSs) revealed that the southern end of the rupture of the 2011 main shock corresponds to the contact region of the Philippine Sea plate and the Pacific plate (Nakahigashi et al., 2012). Therefore revealing a crustal structure around the southern end of the rupture area is indispensable to understanding a seismogenic process. Furthermore, information about the Vp structures and Vp/Vs ratios is needed for a better understanding of large earthquakes that occur as a result of stress-concentration on the plate boundary.

Aftershock observations using OBSs was carried out immediately after the occurrence of the 2011 Tohoku-oki earthquake, and precise aftershock distribution over the whole source area was estimated (March 15th-June 18th, 2011) [Shinohara et al., 2012]. In this study, we estimate precise hypocentral distribution around the southern end of the rupture area using additional date (June 28th-Sep. 13th, 2011) obtained by the aftershock observation by OBSs, and understand a source process of the 2011 Tohoku-oki earthquake.

This study is partly supported by the Spatial Coordination Funds fo the Promotion of Science and Technology (MEXT, Japan) titled as the integrated research for the 2011 off the Pacific coast of Tohoku Earthquake.

Keywords: 2011 Tohoku-oki earthquake, aftershock activity, Ocean Bottom Seismometers (OBSs), crustal structure, Philippine Sea plate, Pacific plate

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(May 19-24 2013 at Makuhari, Chiba, Japan)

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Triggered seismicity in Northern Nagano region at short times after the 2011 M9.0 Tohoku-Oki earthquake

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The changes in seismicity after the 2011 Tohoku-Oki earthquake can be explained in most cases by the Coulomb static stress transfer mechanism (Toda et al., 2011). However, one exception seems to be the seismicity activation in a few inland regions of northeast Japan. Given the compressional tectonic regime in northeast Japan, the seismicity in such areas, after the megathrust event, should have been inhibited rather than activated, if we assume the Coulomb failure criterion. Thus the static stress transfer from the Tohoku-Oki earthquake cannot explain this seismicity increase. It may be possible to relate such activation with dynamic stress changes caused by the passage of surface waves from the 2011 Tohoku-Oki earthquake.

In this study we investigated the possibility of dynamic earthquake triggering in the northern Nagano region, where the seismicity was clearly activated following the 2011 Tohoku-Oki earthquake. An Mw6.2 event occurred here after about 13 hours from the Tohoku-Oki earthquake. According to the Japan Meteorological Agency (JMA) earthquake catalog, there was no recorded earthquake in this region in the first 7 hours after the 2011 Tohoku-Oki event. However, in many cases after large events, the seismicity immediately after the mainshock is incompletely recorded in earthquake catalogs (Kagan, 2004). We used event-waveform data and continuous waveform data recorded at Hi-net stations in Nagano region and apply the Matched Filter Technique (Peng and Zhao, 2009) to detect as many earthquakes as possible in the first hour after the Tohoku-oki earthquake. As a result, we have detected new events (i.e. events that are not in the JMA earthquake catalog) occurring in the first hour after the Tohoku-Oki earthquake. Some of these events are located close to the hypocenter of the Mw6.2 Nagano earthquake (which occurred about 13 hours after Tohoku-Oki earthquake), some others locate to the south, in an area where an Mw5.4 earthquake occurred about one month later. The analysis of F-net Centroid Moment Tensor (CMT) focal mechanism solutions shows that the majority of earthquakes from 2001 until the occurrence of the Tohoku-Oki earthquake differ from those after the M9.0 event. In detail, the thrust fault events are predominant in the region before the Tohoku-oki earthquake, while the dominant mechanism becomes strike-slip after the M9.0 event. The Coulomb failure stress changes cannot explain the focal mechanism changes. Note that the "anomalous" focal mechanisms in the triggered areas are consistent with a fluid-driven seismicity activation (Terakawa et al., 2012).

Based on the above results, we can speculate that the passage of surface waves from the Tohoku-oki earthquake caused enhanced fluid transport and pore pressure changes. These fluid-related changes may have modified the Coulomb failure function in such a way that the effective normal stress is decreased sufficiently to trigger failure (e.g., Cocco and Rice, 2002). We can further speculate that the seismicity occurred at early times after Tohoku-Oki earthquake in the Nagano region contributed through dynamic stress transfer to the occurrence of the nearby Mw6.2 Nagano earthquake.

Keywords: The 2011 M9.0 Tohoku-Oki earthquake, Northern Nagano seismicity, dynamic triggering, cross-correlation, focal mechanism data

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Spatio-temporal occurrence patterns among the foreshocks preceding the 2007 Noto Hanto earthquake

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Foreshocks are a key for understanding the preparation and generation processes of the mainshock. In rock failure experiments, it is well known that acoustic emissions occur prior to the major failure (e.g. Scholz, 1968; Lockner et al., 1992). Recently, analyses of seismograms recorded by a dense seismic observation network have revealed new insights of foreshocks through studying uncataloged smaller foreshocks. Clustered foreshocks adjacent to the mainshock hypocenter with identical seismograms were found for the 1999 Izmit inter-plate earthquake in Turkey (Bouchon et al., 2011) and the 2008 Iwate-Miyagi Inland crustal earthquake in Japan (Doi and Kawakata, 2012). In this study, we try to make it clear how common the clustered foreshock occurrence and to grasp whether other foreshocks occur in total mainshock rupture volume. Focusing on the 2007 Noto Hanto Earthquake with JMA (Japan Metrological Agency) magnitude (Mj) of 6.8, we estimated the spatio-temporal clustered seismicities of the foreshocks in the source region.

By analyzing continuous seismograms that recorded activity in the 25 days before the earthquake, we detected 36 small seismic events around the mainshock hypocenter that classified as members of mainly three clusters. Two clusters included more than ten events and occurred some distance from the mainshock fault, indicating that the clusters did not relate to the mainshock event. The cluster located along the mainshock fault was only the third one. Especially, this cluster was mapped in the same general vicinity as the rupture initiation point of the mainshock and consisted of four foreshocks in succession with identical seismograms. This cluster began twelve minutes before the mainshock and then ceased for period of quiescence for the last eight minutes. The occurrence pattern of this clustered foreshock sequence is similar to that observed in association with the 2008 Iwate-Miyagi Inland earthquake.

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Precursory seismicity change of the 1999 Chi-Chi, Taiwan earthquake revealed by the ETAS model

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In order to investigate the preparatory process of the 1999 Chi-Chi, Taiwan earthquake and the statistical feature of its related seismicity, we applied the Epidemic-Type Aftershock-Sequences model (ETAS model) (Ogata, 1988) to the earthquake data in Taiwan region. By means of the ETAS analysis for Taiwanese earthquakes with magnitudes larger than 2.4, seismic quiescence was found over broader regions of Taiwan, while seismic activation was identified near the source areas of the Chi-Chi earthquake in the period from Jan. 1, 1998 to Sep. 20, 1999, which is just before the occurrence of the Chi-Chi earthquake. The assumption that this is due to precursory slip (stress drop) on the fault plane of the Chi-Chi earthquake is supported by previous researches such as a numerical simulation using rate- and state-dependent friction laws (Kato et al., 1997) and the observation of abnormal change in crustal displacement for a station of Taiwan GPS network near southern edge of the source area of the Chi-Chi earthquake (Hou et al., 2003).

Reference

Kawamura, M. and C.-c. Chen, Precursory change in seismicity revealed by the Epidemic-Type Aftershock-Sequences model: A case study of the 1999 Chi-Chi, Taiwan earthquake, Tectonophysics, accepted.

Keywords: ETAS model, seismic quiescence, seismic activation, seismic activity, precursory slip, the 1999 Chi-Chi earthquake

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Shear fracture strength of faults (VI): Relation between GPS velocity fields and seismic activity

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INTRODUCTION: In this study, the following two problems will be discussed. First, GPS velocity represents the velocity at which constituents of the crust moves. Crustal movements are considered to be caused by the non-uniform motion of the crustal materials. The GPS velocity field is non-uniform even in the intra-plate. In the south Kanto district, the direction of the GPS velocity actually varies from SW to NW as the observation point becomes south. One of the purposes of this study is to discuss the depth where the driving force of the crust is acting. Next, after the 2011 off the Pacific coast of Tohoku Earthquake (2011/3/11, Mw9.0), the seismic activity is high in the east side of either of the lines, the NW-SE line passing through near Kinkazan and the NE-SW line passing through near Iwaki. The similar pattern of the seismic activity is observable off the Ibaraki prefecture and off the Boso peninsula, as well. The other purpose is to make the meanings of the boundary line clear.

THE METHOD AND ITS BACKGROUND: A model of fault zones proposed on the basis of the results of in-situ stress measurement suggests that the strength of a fault is about 10 MPa in the upper crust. This means that the strength is very small, or faults are weak. This implies that a fault plane is nearly parallel to one of principal planes of stress. The comparison of the orientation of the horizontal stresses with the direction of GPS velocity in GRS80 system has revealed that the direction of the largest or the smallest horizontal stress can be approximated by the direction of GPS velocity. Therefore, we can expect that the direction of a fault strike is nearly equal to that of GPS velocity, if one of the principal stresses lies horizontal.

On the basis of the above results, the strike direction of a fault will be compared with that of GPS velocity, using the earthquakes occurring at various depths. This is available for discussing the driving force of the crust. In order to make the meaning of the boundary line clear, it is the first step that the direction of the boundary line is compared with that of GPS velocity.

RESULTS AND CONCLUSION: Focal mechanism solutions have been preliminarily compared with GPS velocities. From this comparison, it is seen that at least one of strike directions and their perpendiculars determined as the focal mechanism solution is close to that of the GPS velocity (1997-2007), even at depths larger than the crust. This suggests that the crust moves together with the upper mantle.

The GPS velocity (1997~2007) lies in SW direction at the GPS stations between Kinkazan and Choshi along the coast of the Pacific Ocean. The boundary line passing through Iwaki is almost parallel to the GPS velocity, and the boundary line passing through Kinkazan is almost perpendicular to it. An earthquake (2011/4/11, Mw 7.1) occurred near Iwaki. Although the strike direction of the nodal plane is determined with wide variety, the direction is almost perpendicular to the GPS velocity. These enable us to think the direction of the GPS velocity as one of the principal directions of stress. The boundary line passing through Kinkazan is almost perpendicular to the GPS velocity (1997-2002) at OSIKA. These suggest that the boundaries of the seismic activity are the boundaries of the crustal structure like as a tectonic line.

The following data are used:
GPS Velocity; GSI, http://mekira.gsi.go.jp/project/f3_10_5/ja/index.html
Seismic activity; NIED, http://www.hinet.bosai.go.jp/
Focal mechanism solution, NIED, http://www.fnet.bosai.go.jp/event/search.php?LANG=ja, and USGS, http://earthq

Keywords: weak fault, GPS velocity, Seismic activity, focal mechanism,, direction of fault strike, tectonic line

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

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A numerical simulation of an aftershock activity with the rate-and-state friction model and secondary aftershock effect

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The model of seismicity rate with rate- and state-dependent constitutive law suggested by Dieterich [1994, JGR] (hereafter referred to as Dieterich model) successfully explains the decay rate of an aftershock activity following an inverse power law (Omori-Utsu law [Utsu, 1961, Geophys. Mag.]). The temporal decay of an earthquake sequence derived from the Dieterich model is asymptotically the same as the particular case of the Omori-Utsu law with the p-value equal to 1, but real aftershock sequences has a variety of the p-value. Some studies have already attempted to resolve this consistency, but it is difficult to reproduce the case of $p > 1$. For this issue, Dieterich [1994] suggests his model including secondary aftershock effect. In this framework, Marsan [2006, JGR] shows the variation on the decay of an aftershock activity with his numerical simulation, but did not discuss how the p-value changes.

This study clarifies the effect of secondary aftershocks on the variety of aftershock decay through a numerical simulation. The approach used in this study is similar to that of Marsan [2006]. Probability distributions of stress changes caused by a mainshock and each aftershock are assumed, and random stress changes which follow the assumed probability distributions are given to a huge number of subfaults. Then, on the basis of the Dieterich model, we compute the seismicity rate with the given stress changes. While Marsan [2006] shows the expected decay of a seismicity rate, in this study earthquake sequences are generated from the computed seismicity rate and the p-values are estimated by fitting the Omori-Utsu formula to each of the generated sequences. The numerical simulation reveals that the p-value depends on the assumed probability distributions of stress changes and that in particular p-value is greater than 1 if the mean of the stress changes caused by aftershocks is positive.

Keywords: aftershock activity, Omori-Utsu law, p-value, rate- and state-dependent friction law, point process analysis, statistical seismology

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Temporary observation of micro earthquakes in the northern Ibaraki prefecture by using ready-made IC recorders

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In order to obtain high quality focal mechanism solutions for earthquakes by using P-wave first-motion polarity data, a dense seismic observation network is required. In this study we propose a new seismic observation system to record a P-wave first-motion polarity. The system consists of a seismometer with a vertical component that price is approximately ten thousand yen and a commercially-supplied IC recorder that price is approximately ten thousand yen. According to the specification of the IC recorder, the recordable frequency band is from 60 to 3400 Hz, Katsumata and Okayama (2012) showed that the IC recorder is able to record seismic waves with a frequency as low as 10 Hz.

In this study, we conducted a temporary observation of micro-earthquakes for one month in the northern Ibaraki prefecture where is the high seismicity area, and addressed the effectiveness of the seismic observation system. The 29 seismic stations were deployed along a road so that it allows a deployment of many stations for a short time. Based on the P-wave first motion polarity, we estimated the focal mechanisms by using HASH program (Hardebeck and Shearer, 2002). In this study, we also use the polarity data recorded at the Hi-net stations that constructed by National Research Institute for Earth Science and Disaster Prevention. We estimated the four focal mechanisms for micro-earthquakes occurred in the study area. Focal mechanisms determined by both Hi-net and the temporary stations were compared with those determined by only Hi-net stations. As a result, we found that focal mechanisms including the temporary stations are more accurate.

For future study we research the frequency specification of the IC recorder in detail, and determine more focal mechanism solutions in the study area. The problems are whether most of them show the normal-faulting type, and whether the seismic observation system developed in this study is really valuable for the studies of focal mechanism.

Keywords: IC recorder

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On the distribution of seismic foci in the Japanese islands and neighborhoods- About the Wadati-Benioff zone

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In this presentation we examine features of distribution of seismic foci in the Japanese islands and neighborhoods, and show some examples of seismic units based on the Research Group of Deep Structure of the Island Arc(2009). We will do a few investigation about Wadati- Benioff zone (Wadati,1935; Usami et al.,1958; Utsu, 1974,1986 another).

The distribution of seismic foci in the Japanese islands and neighborhoods

In the area from west part of Kuril islands to Hokkaido the iso-depth focal contours run in the direction of ENE-WSW or NE-SW and get deeper to NW trend gradually. In the area of Honshu and surrounding area, and in the Japan sea, the iso-depth focal contours run in the direction of ENE-WSW or NE-SW and get deeper to NW trend gradually. In Kyusyu and in the Southwest islands and surrounding areas have a tendency to get deeper from the Ryukyu trench to N-W trend. The outline of the distribution of seismic foci is mentioned above, and by examining minutely we found that very often the iso-depth contours are displaced discontinuously. Displaced parts are straight or arc and its length are 10km or more. Units of the distribution of seismic foci are distinguished from the others on the displaced boundary.

The distribution of seismic foci and seismic unit

We will show the seismic unit on the Kuril basin, Izu-Ogasawara islands and adjacent area, and the central Honshu as a few examples.

The seismic unit around the Kuril basin. There is seismic unit shaped like a half basin getting deeper to the center of the basin and it keeps up with the unit of topography of the Kuril basin. The width of the units divided with displacement line like steps are 50-150km. We recognized these small rectangular units and large units. A large unit is formed with several small units.

The seismic unit around the Izu-Ogasawara Islands and neighborhoods. As a whole, in Izu, Ogasawara Islands and neighborhoods, the iso-depth contours show the direction of NS to NNW-SSE direction, but when some units are distinguished by ENE-WSW direction, the stepped displacement lines of EW direction, and the expanse of these units is number 10-200km.

The seismic unit around the center part of the Honshu. In the direction of iso-depth contour lines, ENE-WSW direction can distinguish some earthquakes area to have an expanse of 100-200km by these in NS to NNW-SSE direction in the Honshu central part whereas the general direction changes to the iso-depth contours in the Honshu central part greatly, and the direction of the iso-depth contours in northeastern Honshu.is displaced step-like after the line of NW-SE direction in NS to NNE-SSW direction.

On the Wadati-Benioff zone

The Wadati-Benioff zone is assumed as a board-shaped thing having the thickness that there is often, but it is divided into the small unit (earthquake area, earthquake sub-region, earthquake region; Adachi,2009) of some that was drawn a boundary with by a stepped displacement line near perpendicularly letting block structure. We want to really reexamine the significance of the Wadati-Benioff zone in future.

Members of the Research Group of Deep Structure of Island Arcs : Adachi H., Akamatsu Y., Harada Y., Iikawa I., Kawakita T., Kobayashi K., Kobayashi M., Koizumi K., Kubota Y., Miyakawa T., Murayama K., Ogawa Y., Sasaki T., Suzuki Y., Suzuki Yo. and Yamasaki K.

Keywords: earthquake, seismic foci, seismic unit, iso-depth contour, Wadati-Benioff zone, Japanese islands

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Wave Features Theory II of 2011, 2 NZ Earthquake Motion

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Japanese only

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Ring-like arrangement of faults accompanied by shallow and deep earthquakes in central Honshu, Japan

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The ring-like arrangement of faults accompanied by shallow earthquakes in central Honshu are shown, and runs parallel to those of deep ones, and it must be due to the vertical deep roots of ring-like arrangement.

Asahi, Iide, Echigo and Abukuma Mountains mainly composed of granitic rocks are dormant in shallow and deep earthquakes, though the shallow earthquakes are active in the north part of the mountains. The general trends of faults accompanied by shallow and deep earthquakes encircle the granitic rocks, and suggest the deep vertical roots of those mountains. The faults deduced from the P-wave radiation pattern of shallow and deep earthquakes run parallel to the Quaternary volcanoes.

Hida, Kiso, Ryohaku, Suzuka, Nunobiki, Kasagi, Ikoma and Rokko Mountains composed of granitic rocks are about 400km in E-W direction and 200km in N-S direction. Central part is composed of Cretaceous Nohi rhyolite encircled by the granitic rocks. It is about 60km in N-S direction and about 40km in E-W direction. The boundary is cut by the deep faults accompanied by deep earthquakes. The deep earthquakes encircling the granitic rocks suggest the deep origin of granitic rocks

The general trends of faults accompanied by shallow and deep earthquakes run roughly parallel each other, so ring-like arrangement from shallow to deep is deduced.

Keywords: shallow earthquake, deep earthquake, earthquake mechanism, fault, ring-like arrangement