Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

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Seismotectonics of collision, stripping and accreting in the South Fossa Magna

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Collision, stripping and accreting have occurred by multiple-collision of the Izu island arc at the South Fossa Magna. It is presumed that this mechanism was occurred intermittently with a great earthquake or a slow slip.

In this study, I apply the study, which I submit this meeting differently, of the mechanism of accreting of the Mineoka block to the area of Izu-Tanzawa region. And I review the tectonics in this area.

First, I redefine next words, collision, stripping and accreting as a matter of convenience.

"Collision" means a state that a release late of relative movement between oceanic plate and hanging wall at an old forward subduction boundary fall to well below 100%.

"Stripping" means an activity of detachment fault, which detaches an oceanic arc crust from an upper mantle.

"Accreting" means a state that stripped oceanic arc crust begins to move as same plate as the hanging wall. In other words, it means a state that an activity of fault at an old forward subduction boundary becomes static.

Second, I categorize a fault which tears an oceanic arc crust off an oceanic plate to three types.

The A-type fault shears an oceanic arc crust and it indicates the property of a normal-fault.

The B-type fault is detachment fault at the oceanic Moho.

The C-type fault shears an oceanic arc crust and it often has high normal stress. So it often becomes strong asperities.

For example, the faults ruptured at latter half of rupture of the 1923 Great Kanto earthquake under the Miura peninsula and at the aftershock occurred three minutes later under the Tokyo bay are an A-type fault conceivably. Moreover, a day later, the aftershock occurred at new usual thrust under southern off Boso peninsula. In fact, it skipped the C-type fault under the Boso peninsula. This C-type fault is equal to the source faults of 1703 Genroku Kanto earthquake. It was revealed that this type of earthquakes has occurred with great slip every about 2300 years. It can attribute this strong asperity to high normal stress at the C-type fault presumably.

Keywords: The South Fossa Magna, Collision, Stripping, accreting, micro semi-plate, detachment fault

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Investigation of plate converging variation off Boso region from multi-channel seismic reflection data

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Off Boso is southeastern offshore region subducting the Philippine Sea and the Pacific Plates respectively at the Sagami Trough and the Japan Trench, beneath the North-American Plate including the Boso Peninsula. Associated with the plate convergences, many earthquakes occurred off Boso region. Great and large earthquakes as the 1703 Genroku and the 1923 Taisho earthquakes occurred by the convergence at the Sagami Trough. The 1677 Enpo and the 1953 Boso earthquakes are thought to be occurred along the Japan Trench generating tsunamis (Hatori, 1975). On the other hand, slow-slip events were observed in every 5-7 year from the east of Boso Peninsula to off Boso region. The slow-slip events off Boso region occurred in the same depth with those of large earthquakes as the 1923 Taisho event. Seismicity off Boso region has changed after the 2011 off the Pacific coast of Tohoku Earthquake: the latest slow-slip event was observed in four-year interval which is shorter than usual. To understand the various seismic activities off Boso region, it is important to image the plate converging variation.

Japan Agency for Marine-Earth Science and Technology has conducted multi-channel seismic reflection survey for imaging the plate converging variation off Boso region. The acquired data was used to select the drill sites for an IODP proposal 'Kanto Asperity Project'. Seismic lines were NE-SW and NW-SE directions, and the latter lines are almost same with the migration of the Philippine Sea Plate. From the seismic data of the former direction, sediments and basements are recognized before subduction of the Sagami Trough. Depth of the basement is about 2-km below sea floor at the southern end of the line. The sediments and basements are observed below thick (~3 km) sediments at the Sagami Trough and below the land plate. In the land plate, there are large amplitude events seemed to be spray faults branching from the top of the Philippine Sea Plate, which are connected to the Boso Escarpment. Around the Boso Escarpment, surface structure was disturbed thought to be caused by deformation of plate convergence. In the northeast of the spray faults, surface sediments (500-700 m) overlie on rugged basements. Drill sites for slow-slip observatory are selected below the basement of which P-wave velocity is about 2 km/s. The top of the Philippine Sea Plate is recognized to the NE end of the seismic line. Amplitude of the reflection is large around the 12-km depth below sea level, which is coincident with the slow-slip region. From the NW-SE profiles, the top of the Philippine Sea Plate is also large amplitude in the slow-slip region, whereas those of the southeast of the slow-slip region are small amplitude. From the observation, the distribution of large amplitude reflection of top of the Philippine Sea Plate is correlated with the slow-slip area. Landward dipping events are observed in the shallow part of the land plate thought to be caused by deformation. However those events are not recognized in the vicinity of the Japan Trench. In this presentation, we will show variations and characteristics of the sediments, basements and plate boundary, and discuss the various seismic activities off Boso region.

Keywords: MCS, Off Boso, earthquake, Philippine Sea Plate, Slow slip

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Fault distribution and shallow structure around the Boso escarpment in the Sagami Trough

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Around the Boso Peninsula, central Japan, the Philippine Sea (PHS) plate is subducting beneath the Honshu Island along the Sagami Trough and the Pacific Plate is subducting beneath the PHS plate and the Honshu Island along the Japan Trench. The area offshore Boso Peninsula has very complicated geological histories by the influence of highly oblique convergence of the PHS plate and collision of the Izu-Bonin Arc since 15Ma. The geologic body of this region is composed of accretionary complex, some part of which is exposed in the Miura and the southern Boso Peninsulas. The geologic body of the offshore Boso Peninsula is also considered as the accretionary complex. Moreover, this area is accompanied with the seismogenic zone in which the great earthquakes such as the 1703 Genroku and 1923 Taisho Kanto earthquakes repeatedly occurred. Additionally, the tsunami and crustal movements also occurred together with earthquakes in this area. In the case of the 1703 Genroku earthquake, it is indicated that the tsunami height at the eastside coast of the Boso Peninsula was a maximum of about 10 m. From this result, it is thought that the earthquake fault of the Genroku event exists around the Boso escarpment. However, the fault distributions around the Boso escarpment have not been yet well understood.

The objective of this study is to elucidate the shallow structure and fault distribution around the Boso escarpment in the Sagami Trough using various kinds of data sets as the swath bathymetric map, IZANAGI side-scan imagery, Multi-Channel Seismic (MCS) reflection profiles, and Single-Channel Seismic (SCS) reflection profiles. These data sets were acquired by JAMSTEC, Japan Coast Guard and ORI, Univ. Tokyo, respectively.

Around the Boso escarpment, geomorhological lineaments were recognized in swath bathymetric map and side-scan sonar imagery. These lineaments are interpreted to be continuous fault scarp morphologies. These lineaments are distributed in the form of the en echelon arrangement in the W-E or WNW-SSE directions. MCS profiles of the area offshore Boso Peninsula provided very clear images of the upper boundary of PHS plate (UPHS) and the forearc area of the Honshu arc composed of the accretionary complex. Landward dipping faults were recognized in the accretionary prism between the Boso and the Katsuura canyons. These faults are distributed along the Sagami Trough and interpreted as splay faults branched from UPHS (Kimura et al., 2009). A number of the splay faults were reached near the seafloor around the top of the Boso escarpment. The seafloor configuration around one of the splay faults clearly indicates that this fault deformed the seafloor recently. The sedimentary basin located above a splay fault shows some evidences of crustal movement: landward tilted reflectors, unconformity with onlap by uplifting and deformations of the shallow part of the basin sediment and the seafloor. These results suggest that the sedimentary basin have been affected by repeatedly faulting. Additionally, faults beneath the sedimentary basin are active.

Keywords: Kanto earthquake, Active fault

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The 2011 Boso slow slip event

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There occurred four slow slip events (SSE) offshore of the Boso peninsula in 1996, 2002, 2007, and 2011 with a recurrence interval of 4 to 6 years. In all cases, it took approximately 10 days for the Boso SSEs to subside. In addition, the past four Boso SSEs occurred in similar areas, indicating characteristic behaviors as was observed in ordinary earthquakes. In this research, we estimate spatial and temporal evolution of aseismic slip of the four Boso SSEs by time dependent inversion.

The GPS network detected transient crustal deformation on the Boso peninsula in 1996, 2002, 2007, and 2011. The detected transient displacements subsided for approximately 10 days. To emphasize transient displacements, we removed a steady deformation from the raw time series. The detrended crustal deformation shows south-southeastward displacements. The maximum detrended deformations are 1.c cm in May 1996, 2.5 cm in October 2002, 2.2 cm in August 2007, and 3.9 cm in November 2011.The observed transient deformation is thought to be caused by the Boso Slow Slip Events (Boso SSE)

We employed time dependent inversion to the detrended crustal deformation associated with the Boso SSEs. We used EW, NS, and UD components of crustal deformation at approximately 40 GPS sites relative to Yasato station. The plate geometry of the upper surface of the Philippine Sea plate is based on Nakajima and Hasegawa [2006]. The fault geometry is expressed by superposition of B-spline functions and slip on the fault is also composed of superposition of B-spline function. Trend and annual components are removed from the raw time series as mentioned above. As boundary condition, we set 0 slip on the edge of a fault geometry.

The results show that the slow slip started offshore of the Boso peninsula and expanded to the south over time in the 1996, 2002, 2007 and 2011 cases. In the case of the 2007 event, slow slip also expanded to the north. The estimated moment magnitudes are 6.7 in 1996, 6.7 in 2002, 6.7 in 2007 and 6.9 in 2011. A similar area was ruptured by the four Boso SSEs with a similar magnitude and a rupture process. The recurrence interval is 6.39 year from 1996 to 2002 events, 4.86 years from 2002 to 2007 events, and 4.28 year from 2007 to 2011 events. The four events do not seem to be slip predictable nor time predictable. Though the 2011 event shows the largest magnitude among the four cases, recurrence interval from the 2007 event is the shortest. We cannot rule out a possibility that the Tohoku earthquake may have affected the occurrence of the 2011 event. In fact, dCFF increased near the rupture area of the Boso peninsula from the Tohoku earthquake.

We will investigate a stress state change in the peripheral area of the 2011 Boso SSEs.

Keywords: Boso peninsula, slow slip event

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Vertical deformation due to slow slips off the Boso Peninsula from leveling data using smoothed data fitting with ABIC

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1. Introduction

Slow slip events (SSEs) and swarm earthquakes off the Boso Peninsula have occurred at intervals of about six years. SSEs are slips that occur slowly over 10days on the plate boundary between North American plate and Philippine Sea plate. The maximum amount of the slip is about 10cm, and the magnitude is about Mw6.5. Displacements due to the events have been monitored 4 times after 1996 when GPS continuous observation began. Before 1996, the SSEs are supposed to be in 1990, 1983, and 1977 from record of tiltmeter or swarm earthquakes. But in order to know what kind of crustal deformation occurred, it needs to analyze the geodetic survey data first. Leveling of Chiba Prefecture has been conducted each year since the 1970s, so it is useful for investigating the crustal deformation due to SSEs. However, the leveling data released by Chiba Prefecture is calculated with fixing two or more level points. Therefore, small up-down change caused by SSEs may disappear. Then, we analyze leveling data before setting up fixed points, and get annual displacements of the Boso Peninsula.

2. Data and Analysis

We obtain leveling data about 864 level points that are located in Chiba Prefecture during the period from 1977 to 1979, 1994 to 2009. In analysis, we use two-dimensional spline function for space, set a constraint on vertical deformation being smooth in space. To determine the best degree of this constraint, we use ABIC.

3. Result

We get vertical deformation by SSEs off the Boso Peninsula. As a result, the years SSEs occurred have a characteristic pattern that the Kujukuri region subsides compared with average year. It is consistent with estimation from GPS data. Furthermore, we estimate the slip distributions which cause the obtained deformations with a forward modeling. From the results, we may estimate slip distributions of SSEs before GPS observation using leveling data.

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We use leveling data by Geographical Survey Institute Kanto Regional Survey Department, Chiba Prefecture Environmental and Community Affairs Department Water Quality Division, and Environmental Research Center.

Keywords: crustal deformation, leveling, slow slip, ABIC

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Observation plan of Ocean Bottom Pressure sensor for recognizing slow slip events at the off Boso Peninsula

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1. Introduction

The Kanto Asperity Project (KAP) sets two main objectives as follows. (1) To understand why the three different types of events occur laterally, at similar depths in the Sagami Trough. (2) To establish realistic earthquake-generation models using data obtained at each step of the process of the slow slip events (SSEs) off the Boso. The KAP-B is a monitoring project, and focuses on the second objective. The KAP-B plans a borehole observation network with high sensitive tilt meters. However, seaward slip area of the SSEs has not been fixed because observation points are placed on the land only. It is important for determining borehole sites to obtain whole slip area of the Boso SSEs. In order to clarify the whole slip area, we will use Ocean Bottom Pressure sensor (OBP) which is relatively inexpensive and easy to set up. In this study, we obtain an appropriate distribution of observatories for recognizing the whole slip area, and then we would like to suggest the plan for observation.

2. Methods

We estimated the error of OBP from the data which had been taken at Mariana back-arc basin in 2010. After the removal of tidal component from the data, we removed the component of ocean movement due to meteorological activity or oceanic current, by the differences between two data which had been taken at the similar location. As we eliminated both tidal and ocean movement component, we obtained that the gap from trend component has about 5mm of standard deviation. Hence, we considered that OBP has an error of 5mm approximately, and we applied this to the inversion analysis.

Next, we put a slip distribution at the offshore of the Boso peninsula, and created a synthetic observation data by adding errors. We applied this synthetic data to the inversion analysis. We conducted inversion analysis by using the program based on the inversion method which was introduced by Yabuki and Matsu'ura(1992) that has prior constraints that fault slips distribute smoothly. Evaluating estimated slips and its errors, we estimated the distribution of observatories which can recognize the slips effectively. Referring to the slip area which is estimated in 1996,2002, and 2007(Ozawa et al.2007), we put 4 slips which slip southeastward, 10cm amount and have an extent of 20 square kilometers. In order to recognizing 4 slip regions, we inspected the distribution of observation points which can detect the slip in high resolution with the least number.

3. results

We put 12 observation points as lattice form. Tiltmeter and GPS are already located on the land therefore, we removed the points which are close to the land, and reduced its number gradually. As a result, we realized that 6 observation points at the offshore can resolve the 4 slips sufficiently. However, if we use 6 points, the error of some places will get increase, so we concluded that we recommend another point to put for reducing the error, and put 7 points in total.

Acknowledgments

The survey with OBP was conducted by R/V Yokosuka.

Keywords: Ocean bottom pressure sensor, slow slip, obsevation plan, KAP