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

SCG063-P01 Room:Convention Hall Time:May 26 10:30-13:00

Mechanical buckling of oceanic lithosphere and subduction zone morphology

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We present a new concept of the physical background of the global-scale distribution of plate subduction zones, especially around the Pacific ocean, using structural mechanics theory such as those presented by Huang (1964) etc.

According to the compilation by Watts (2001), the elastic layer thickness of oceanic lithosphere is approximately 25km for the 30Ma lithosphere, and is approximately 60km for the 130 - 140Ma.

Assuming the earth' s radius of 6.371 x 10^3 km, and the Poisson ratio of 1/3, etc., in the case of great-circle shape of the global subduction zones with the uniform slab age of 130-140Ma, the result of Huang (1964) suggests that the preferable wave number, parallel to the circumferential direction, of global spherical buckling becomes approximately 12. In other words, the classical result of Huang (1964) suggests the preferable spherical buckling wavelength of the great-circle subduction zone with the 130-140Ma slab is approximately $3.3\text{x}10^3$km. For the spherical buckling of younger slab than 130-140Ma for the great-circle subduction zone, the preferable spherical buckling wavelength is smaller than approximately $3.3\text{x}10^3$km.

Whereas, referring to a recent numerical simulation study on the spherical buckling by Mahadevan et al. (2010), we can suggest that the preferable spherical buckling wavelength of the great-circle subduction zone for the 130-140Ma and 30Ma slab are approximately $1.7\text{x}10^3$km and $9\text{x}10^2$km, respectively.

However, the above estimation might not be conclusive, because these models don't incorporate dynamic influence originated from the vertical slab extent (especially, whether stagnated at 660km depth, or not), and the ambient mantle flow regime, etc.

In addition, if a certain local portion along the subduction zone segment, during the bucking mode change of subducting lithosphere, has been mechanically fixed to the mantle frame, the forthcoming morphological transforming process of the trench - arc - back-arc system will be constrained by the non-moving site.

In general, the geometrical change of subduction zone due to the spherical shell deformation would provide the instantaneous and long-term responses on various fields of geodesy, geophysics, geology and mineral physics, etc.

We also suggest that the above dynamics is applicable on the other terrestrial planets with plate tectonics.

Keywords: subduction zone, oceanic lithosphere, buckling, spherical shell

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Numerical simulation of incipient plate subduction on intra-oceanic plate boundaries with Distinct Element Method

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Plate convergent margins bring the main driving forces to activate the plate tectonics on the earth. However, the initial formation process of new plate convergent margins has not yet to be adequately described. We constructed numerical models imitating intra-oceanic plate convergent margin, and examined numerical experiments. These convergent margins were constructed by the Distinct Element Method (DEM) that was extended to incorporate ductile deformation by a newly developed 'balloon method'. One plate convergent margin was constructed as one pair of adjacent two plates, and four different pairs of plate thicknesses were set as initial conditions. The two of four experiments showed initial plate subduction, and the results shows that plate subduction starts with a well grown slab head and the flow of asthenospheric mantle beneath lithospheric plate strongly affects to formation of plate convergent margins.

Keywords: plate tectonics, convergent margin, plate subduction, numerical computing

Japan Geoscience Union Meeting 2011
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SCG063-P03 Room:Convention Hall Time:May 26 10:30-13:00

Afterslip and viscoelastic relaxation due to the 2004 Sumatra earthquake seen from GRACE gravity field

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Geodetic observations have revealed that a large earthquake can cause post-seismic crustal deformation that continues for more than a decade. Investigating mechanisms of post-seismic deformation gives a clue to infer the stress change in space and time on a plate boundary. To elucidate the stress history is important to identify if we are already in the preparation stage for the next event or still in the post-seismic stage of the previous event in the context of earthquake cycle. The diagnosis becomes complicated because various mechanisms displaying different stress behaviors have been proposed, such as afterslip, poroelastic rebound, and viscoelastic relaxation. Surface crustal deformation data have frequently indicated that contributions from different mechanisms are superimposed. The combination of short-term afterslip and long-term viscoelastic relaxation is considered as a representative mechanism for a thrust-type large earthquake in a plate subduction zone. However, when the epicenter is surrounded by the ocean, as often seen in island arc, a clear separation is prevented because a sufficient spatial coverage cannot be obtained by terrestrial observation to distinguish surface deformations expected from those mechanisms. Recently, GRACE satellites have detected post-seismic gravity variations due to the 2004 Sumatra-Andaman earthquake. Satellite gravity data can be obtained over the ocean. In addition, measuring the density redistribution which reflects deformation in a deeper portion of the earth emphasizes the difference between afterslip and viscoelastic relaxation. In the presentation, we use GRACE data for 2003-2010 and show that afterslip and viscoelastic relaxation by the 2004 event can be effectively separated. To accurately model a long-wavelength gravity variation caused by those mechanisms, we develop a spectral finite-element method based on FEM and analytic expression by spherical harmonic tensors. This allows us to consider effects of compressibility of crust and mantle, a strong lateral heterogeneity in the viscosity due to the presence of a slab, and self gravitation in a spherical earth that have not been simultaneously considered in most previous models. GRACE data are corrected for using ECCO Ocean model and GLDAS hydrological models. Most of the remaining signal can be explained by viscoelastic relaxation for a mantle viscosity of 3 x 10ˆ18 Pas. The spatial pattern in the observed gravity field obtained by subtracting the estimated viscoelastic relaxation agrees with that predicted by afterslip. In particular, the trend expected from afterslip and that expected from viscoelastic relaxation is reverse in a region over the ocean. This indicates that the both mechanisms are needed to explain the observed data. The superposition of short-term afterslip and viscoelastic relaxation is consistent also with a result by GPS observation. Our result indicates a validity of satellite gravity observation data for studying mechanisms of post-seismic deformation.

Keywords: crustal deformation, gravity, postseismic deformation, viscoelasticity, satellite gravity mission, geodesy

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Structure and evolution of active faults with strike-slip in a forearc basin: An example of Enshu fault system in the ea

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1. Introduction

Accretionary prisms and forearc basins are developed in the Nankai Trough, SW Japan. Many active faults are recognized and classified into five fault systems in the eastern Nankai Trough. The most landward Enshu Faults System runs over 200 km along the northern margins of the Tokai and Kumano forearc basins. Swath bathymetry and side-scan sonar surveys indicate a general fault trend of ENE-WSW and dextral displacement of submarine canyons. However, there is no report about the history of the active faults. Fault activities have been recorded in sedimentary sequences, because sedimentation in a forearc basin is very active in this area. Therefore, fault activity histories can be restored by seismic reflection records. Structural investigation of this area is important for earthquake disaster mitigation as well as understanding of oblique subduction tectonics because this area is closed to densely populated cities.

2. Data source

This study is based on data from seismic reflection survey "Tokai-Kumano Nada" in 2001 and MITI well 'Nankai Trough' in 1999 conducted by Japan Oil, Gas and Metal National Corporation (JOGMEC) (Fig. 1). 3.5 kHz sub-bottom profiles and chirp sub-bottom profiles obtined during KH-10-3 cruise in 2010 and IZANAGI side-scan sonar images are also used in this study.

3. Results and Discussion

3-1. Seismic stratigraphy

This study picked continuous reflectors and divided the formation into five units. Moreover, these units were correlated with core data from MITI Well "Nankai Trough" and got to correspond to Ogasa Group, Upper Kakegawa Group, Mid Kakegawa Group, Lower Kakegawa Group and Basement (Saigo/Kurami Group), respectively (Fig. 2).

3-2. Terrace structure and Lineament

IZANAGI side-scan sonar image showed the NEN-SWS trending three lineaments parallel to each other on a seafloor (from north to south, L-1, L-2, L-3). Seismic reflection profiles indicate that faults are developed beneath each lineament. It is thought that displacements of active faults formed basin structures and terrace morphologies on a seafloor.

3-3. Flower structure and Strike-slip fault

Seismic reflection profiles indicate that most reverse faults developed beneath lineaments seem to have strike-slip component judging from existences of flower structures. Riedel shear deformations were observed on the Shima Spur, and horizontal shift was recognized at an axis of Anoriguchi submarine canyon. These observations are consistent with strikes-slip deformation. Moreover, shallow extension of fault planes on seismic reflection profiles and cold seeps observed by submersibles, strongly suggest that most faults are active in this area.

3-4. Restoration of activity in strike-slip fault

An isopach map of each unit was made on the basis of seismic stratigraphy. Seismic profiles in E-W direction show discontinuous reflectors suggesting paleo-submarine canyons (Takano et al., 2010) in Units 3 and 4. Unit 3 exhibits horizontal stepwise displacement of a region with uniform sediment thickness. It seems that dextral strike-slip fault displaced a paleo-submarine canyon. Above Unit 2, there is no deformation structure suggesting strike-slip displacement. In summary, fault activity of the lower units (Units 3 and 4) seems to be higher than that of the upper units (Units 1 and 2).

3-5. Restoration of activity in reverse fault

In general, reverse faulting is accompanied by thick sedimentary sequence in a footwall side. Such structures are well developed in Unit 4, and partly recognized in Unit 3. In addition, reverse faults were active in the formations lower than Unit 4 by vertical displacements in seismic reflection profiles. In contrast, the faults seem to be inactive above Unit 2. Vertical displacements of Units 1 and 3 show large differences from place by place along lineaments. The cause of this deformation pattern is explained by subduction of a basement high.

Keywords: Nankai Trough, Forearc basin, Reverse fault, Strike-slip fault, Seismic reflection survey

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Crustal movement in the past 100,000 years in Ise Bay and Ohmi Basin, based on geomorphology and subsurface geology

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I estimated tectonic movement in the past 100,000 years around the Yoro-Kuwana-Yokkaichi fault zone. I carried out aerial photograph interpretation to classify and correlate terrace surfaces and identify tectonic geomorphology. Additionally, I conducted cryptotephra analysis to constrain the ages of terrace surfaces in the northern part of the Kinki Triangle. Vertical displacement is estimated based on terrace surfaces and subsurface geology. Vertical slip rates are estimated as the Yoro fault: $>$1.2 mm/yr (only subsidence rate), the Kuwana fault: $>$1.0-1.1 mm/yr, the Yokkaichi fault: 0.4-0.5 mm/yr.

Keywords: Ise Bay, Ohmi Basin, crustal movement

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SCG063-P06 Room:Convention Hall Time:May 26 10:30-13:00

Denudation history of the Akaishi Range, central Japan, based on low-temperature thermochronology

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We conducted low-temperature thermochronometric analysis to constrain denudation history of the Akaishi Range. ZHe ages of 20-3.5 Ma were obtained between the MTL (Median Tectonic Line) and ISTL (Itoigawa-Shizuoka Tectonic Line). These data are preliminary interpreted as below: 1) the youngest age, ~3.5 Ma, indicates the upper limit of the onset of the denudation event, which roughly corresponds with the onset of the uplift of the Akaishi Range estimated by previous studies, 2) younger ZHe ages to the east implies westward tilting of the Akaishi Range, 3) assuming geothermal gradient of ~30 deg.C/km and surface temperature of ~20 deg.C, the denudation in the past ~3.5 Ma is calculated at 5-6 km near the ISTL at the eastern margin of the Akaishi Range.

Keywords: fission-track thermochronology, (U-Th)/He thermochronometry, Akaishi Range, denudation

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Postseismic deformation due to the 2008 Iwate-Miyagi Nairiku earthquake: follow-up study

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At 2009 JPGU meeting, we have presented the post-seismic deformation signals associated with the 2008 Iwate-Miyagi Nairiku Earthquake (2008 June 14 JST, M6.8) detected by interferometric synthetic aperture radar (InSAR) analysis using ALOS/PALSAR data. Due to an orbital change of ALOS, however, only a few InSAR images with small perpendicular base-line were available at that time, which made our conclusion less accurate. Fortunately, ALOS changed its orbit again and much short base-line InSAR pairs became available. By adding those better InSAR images, we have confirmed our previous conclusion and point out more detailed characteristics of the post-seismic deformation.

As we have already presented, the post-seismic deformation signal is characterized by length changes in radar line-of-sight (LOS) to the east of Mt. Kurikoma (KRK), to the south of KRK, around Mt. Amadamori (AMM), and to the east of Mt.Kunimiyama (KNM). Further InSAR analysis illustrated time-dependent nature of the post-seismic deformation. Also, we found a clear correspondence of the coseismic surface deformation derived from pixel offset technique (Takada et al., 2009) to the post-seismic surface deformation, with which we can delineate coseismic fault shape. Through this study, we demonstrated that ALOS/PALSAR has strong ability to detect surface deformation lurking in such a vast mountainous area.

Acknowledgements: PALSAR Level 1.0 data in this study are provided from PIXEL under a cooperative research contract with ERI, Univ. Tokyo and the Earthquake WG established by JAXA. The ownership of ALOS/PALSAR data belongs to METI/JAXA, Japan.

Keywords: 2008 Iwate-Miyagi Nairiku Earthquake, Postseismic deformation, InSAR, Time evolution

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Spatiotemporal variation of crustal deformation in northeast Japan estimated from GPS data

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Crustal deformation along the plate subduction zone contains both of the long-term intraplate deformation and the short-term elastic deformation caused by plate interactions on the plate boundary surface. To separate these two contributions and presume both quantitatively are necessary for understanding the deformation physics along the plate subduction zone. It has been clarified that intermittent slip phenomena are generated on the plate boundary surface during interseismic period, for example the slow slip event and the low frequency tremor (e.g. Obara et al., 2002; Ozawa et al., 2002). Thus, it has to be considered for understanding quantitatively how strains are accumulated in seismic cycle to estimate the temporal variation of interplate locking after the separation of two deformation signals mentioned above.

In northeast Japan, the 1993 Hokkaido Nansei-oki (M7.8), 1994 Sanriku-oki (M7.6), and 2003 Tokachi-oki (M8.0) earthquakes have occurred since nineties, when the nationwide continuous GPS observation network was installed. Coseismic and postseismic deformations are observed at these GPS sites (e.g. Nishimura et al., 2004; Ozawa et al., 2007). We focus on time variations of interplate locking, which is like stress accumulation -> coseismic slip -> postseismic slip -> locking recovery -> stress accumulation. On the other hand, Kimura and Kusumoto (1997) suggested that the Chishima forearc region along the Chishima Trench behaves like a block and it migrates to westward with respect to Japan arc. It implied the possibility of intraplate deformation in upper plate along the Chishima Trench.

We analyze the crustal deformation in northeast Japan using block fault model to estimate contributions of the intraplate deformation and plate interaction, quantitatively. We use the dairy coordinate solution (F3) of nationwide continuous GPS network from 1996 to 2010 operated by the Geospatial Information Authority of Japan. We divided whole coordinate data into every two years, and then estimated the average displacement rate at each period. We used the block fault model developed by McCaffrey (2002) in our analysis. Using this model, we simultaneously estimated the rigid rotation of the Chishima forearc and the contributions of the plate interaction along the Chishima-Japan Trench and the eastern margin of the Sea of Japan. In our presentation, we show the temporal variation of interplate locking distribution and discuss how interplate locking is recovered after earthquake occurred.

Keywords: GPS, block fault model, interplate earthquake, after slip, fault healing, Northeast Japan

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Seismic reflection and gravity survey across the Eastern Boundary Fault Zone of Ishikari Lowland, Hokkaido; Line 1

Shinsuke Okada[1*], Kazuo Yamaguchi[1], Tatsuya Sumita[1], Masahiko Makino[1], Takanobu Yokokura[1]

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The Eastern Boundary Fault Zone of Ishikari Plain is a zone of North-South trending reverse faults, which border the eastern margin of Ishikari lowland with length of about 65 km length. Active faulting on the Eastern Boundary Fault Zone of Ishikari Lowland shows the latest faulting of Hidaka fold-and-thrust belt that is collision between the Northeast Japan arc and fore-arc sliver of Kuril arc, which is driven by oblique subduction of Pacific plate.

To reveal the subsurface structure of the Eastern Boundary Fault Zone of Ishikari Lowland, we carried out two lines of seismic reflection and gravity survey in November 2010. Seismic line 1 has a length of 19.2 km and started from Hayakita-midorigaoka in Abira town to Kashihara in Tomakomai city along Rout 234. Seismic line 2 has a length of 8.8 km and started from Kashiwadai-minami in Chitose city toward the direction of ENE through the Higashi-chitose Self Defense Force military station. The source used in this seismic survey was a vibrator (Y-2400; IVI Inc.). The receiver was SG-10 (natural frequency, 10 Hz; Sercel Inc.). The source and receiver spacing was 10 m, with 240-ch geophones used for each recording. We selected the DSS-12 (Suncoh Consultants Co., Ltd) for the recording system and its sampling rate is 2 msec. Spacing of each gravity stations along seismic lines and its extension is 250 m standard. We applied D-type gravity meter of LaCoste & Romberg (D-205). To acquire the global position of each gravity station and its altitude, we used Trimble R8 GPS system. 79 gravity stations along Line 1 and its extension and 61 gravity stations along Line2 and its extension were measured in this survey. In this presentation, we focus on the result of seismic and gravity survey along Line 1.

We would like to thank Higashi-chitose Self Defense Force, Abira town office, Tomakomai city office, and Hokkaido Regional Development Bureau for their cooperation.

Keywords: seismic reflection profiling, gravity survey, the Eastern Boundary Fault Zone of Ishikari Lowland, Umaoi Hills, subsurface structure

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Seismic reflection and gravity survey across the Eastern Boundary Fault Zone of Ishikari Lowland, Hokkaido; Line 2

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We would like to thank Higashi-chitose Self Defense Force, Abira town office, Tomakomai city office, and Hokkaido Regional Development Bureau for their cooperation.

Keywords: seismic reflection profiling, gravity survey, the Eastern Boundary Fault Zone of Ishikari Lowland, Umaoi Hills, sub-surface structure

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Determination of fault plane solutions of small events in Hokkaido associated with the motion of Kuril fore-arc sliver

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In order to find the evidence of transcurrent movement of fore-arc sliver along the southern Kuril trench, we determined the fault plane solutions of smaller events using the method developed by Imanishi et al.(2006). We used P- and SH-wave amplitudes as well as P-wave polarity and determined fault plane solutions with magnitude range from 2.0 to 3.5 and the numbers of P-wave polarity data are 10 or greater. Especially we focused on the fault plane solutions along the estimated boundary of the fore-arc sliver in Hokkaido. We find the fault plane solutions of strike-slip type with the nodal plane of right-lateral slip along the volcanic front. While strike-slip events determined by F-net from 1997 to 2009 concentrate around Teshikaga area, those events determined by this study are distributed along the volcanic front continuously. Around the central Hokkaido where the Hidaka Mountains and volcanic front intersect, strike-slip types with P-axis trending E-W direction were also determined.

In the western side of Hidaka Mountains, we find the fault plane solutions of thrust and strike-slip type with P-axis parallel to the trench. Thrust events are distributed along the Conrad discontinuity or within the lower crust of Northeastern Japan arc inferred from seismic refraction/wide-angle reflection experiments by Iwasaki et al.(2004). On the other hand, Events of strike-slip type are distributed within mantle wedge of Northeastern Japan arc. In the eastern side of Hidaka Mountains, we find the fault plane solutions of reverse type of events with P-axis parallel to the dip direction of descending lower crust due to the delamination of the crust of Kuril arc.

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A geomorphological analysis of the Kumukol Basin at the northeastern edge of the Tibetan plateau using ALOS stereoscopic

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The area of the Tibetan plateau has been expanded laterally after it had attained an equilibrium elevation. The mechanism of lateral growth may be different from region to region. Along the southern edge of the Himalayas, for example, the plate-boundary thrust fault has repeatedly jumped southward, invading stable continental lithosphere on the foreland side. In this area discrete and episodic growth has occurred. In contrast, the lateral growth in Yunnan is continuous growth in space and possibly in time (Clark and Royden, 2000). However, the growth mechanism at the northern edge of Tibetan plateau has not revealed yet.

First, in this study, using global gravity anomaly data, we compared the characteristics of plateau margins in Himalaya and Yunnan with those in the northeastern edge of the plateau. We inferred that a complex and different type of growth occurred at the northeastern edge. So we searched the tectonic relief in Qaidam basin that is located at the northeastern edge of the Tibetan plateau. We found that there is a long-wave anticlinorium in the Kumukol basin (Kumukol Anticlinorium) located in the southern margin of Qaidam basin, and that there are many anticlines, faults and terraces on the surface of this anticlinorium.

Then we analyzed these tectonic features in more detail by the use of GIS software (ArcGIS). Topography data that we mainly used is the SRTM3 DEM with 3-arc second resolution. We also analyzed satellite images with 2.5-meter resolution, which were obtained by the PRISM sensor on the ALOS (Advanced Land Observing Satellite).

It was observed that there are high, middle and low groups of terraces, which were developed across the eastern part of the Kumukol Anticlinorium. Geomorphological analysis revealed that the amounts of vertical displacement with respect to the present river floor are accumulated more in higher terraces than in lower terraces, which terraces are likely to have been developed in response to advances and retreats of alpine glaciers in the surrounding mountains. Moreover by photogeological survey we inferred that Kumukol Anticlinorium is formed by activity of north dipping fault.

Keywords: Tibetan Plateau, Lateral growth, Qaidam Basin, Tectonic landform