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

SCG66-01 Room:201A Time:May 24 09:00-09:15

Spatio-temporal renewal model for repeating earthquakes and analysis of slip rate on plate boundaries

Shunichi Nomura[1*], Yosihiko Ogata[1], NADEAU, Robert M.[2], Naoki Uchida[3]

[1]The Institute of Statistical Mathematics, [2]University of California, Berkeley, [3]Graduate School of Science, Tohoku University

We propose a new spatio-temporal stochastic model based on a renewal process to estimate quasi-static slip rate from repeating earthquakes on plate boundaries.

A renewal process is a point process that assumes intervals of events are independently and identically distributed. It is applied to long-term forecast of large earthquakes in active faults or on plate boundaries. But when we apply it to small repeating earthquakes, the assumption of stationarity in renewal processes often fails because their intervals are influenced largely by the change in slip rate near their hypocenters.

Thus, we consider a non-stationary renewal process that the repeating intervals are inversely proportional to their neighbourhood slip rate. We introduce the space-time structure into this model by smooth cubic B-spline functions allocated to partitioned grids. On estimating the coefficients of spline bases, we use a penalty function for unsmooth change into the model to avoid over-fitting for the dataset. Optimal hyper-parameters are selected by Akaike's Bayesian Infromation Criteria (ABIC). We use relations between magnitudes and slip lengths of repeating earthquakes derived by Nadeau and Johnson (1998) to estimate the absolute slip rate.

We apply this model to the set of repeating earthquake sequences in Parkfield segment of San Andreas Fault, California. From the result of analysis, we see the accelaration of slip from 1993 and afterslip of larger earthquakes at M4.6. We also analyze the aftershocks in repeating sequences after 9/28/2004 Parkfield earthquake at M6.0.

Proposal model can estimate slip rate at depth where GPS system can not measure directly. Although it is difficult to estimate coseismic slip of large earthquakes from repeating earthquakes, this model can monitor the characteristic change in slip rate.

Keywords: repeating earthquake, slip rate, spatio-temporal analysis, renewal process

SCG66-02 Room:201A Time:May 24 09:15-09:30

Temporal acceleration of the Pacific Plate subduction by a deep earthquake

Kosuke Heki[1*], Yuta Mitsui[1]

[1]Dept. Natural History Sci., Hokkaido University

Landward velocities of GPS points accelerated on segments adjacent to the segments ruptured in the 2003 Tokachi-Oki (Mw8.0) and the 2011 Tohoku-Oki (Mw9.0) earthquakes in NE Japan. Sea floor GPS measurements by Japan Coast Guard also revealed fast post-2011 landward movement of MYG1 reaching ˜30 cm per year. From these observations, we hypothesized that the movement of the Pacific Plate slab was accelerated after mega-thrust earthquakes (Heki and Mitsui, EPSL 2013). The accelerated velocities are considered to have reached ˜1.5 and ˜3 times as fast as the geological average.

During interseismic periods, the balance between the up-dip forces (viscous side resistance and interplate coupling) and down-dip forces (slab pull and ridge push) realizes constant subduction velocity (Seno, 2001). Megathrust earthquakes reduces interplate coupling, and let down-dip force temporarily exceed the other forces. Then the slab is accelerated downward, and increased side resistance will achieve new force balance. Accelerated regime would be temporary and time-averaged rate is expected to resume as interplate coupling recovers.

Past examples suggest that within-slab seismicity of down-dip compression mechanisms is activated in the deep part of subducting slabs (Lay et al., PEPI 1989). This would reflect the increase of the edge resistance caused by the slab acceleration. After the 2012 Tohoku-Oki earthquake, an Mw7.7 deep earthquake occurred close to the down-dip end of the Pacific Plate slab beneath Sakhalin, Russia, on August 14, 2012.

GPS stations in the eastern Hokkaido are known to have significantly accelerated landward after the 2011 Tohoku-Oki earthquake (Fig.5 of Heki and Mitsui (2013)). The attached figure shows the movements of the Shari, Bekkai, Nemuro, Hanamaka, and Kushiro-city GPS stations toward the trench (N150E) during 2008-2013 based on the F3 solution of GEONET. To isolate post-2011 trend changes, we removed the linear component estimated using the portion from 2008/1/1 to 2011/3/11. In addition to the coseismic steps of the Tohoku-Oki earthquake, negative changes in trends (i.e. landward acceleration) are clear. Afterslip shows large temporal decay characterized by the time constant of ˜0.4 years (Ozawa et al., 2012), but we see only small such decay in these stations. Hence, these landward movements would reflect the apparent enhancement of coupling due to the acceleration of the Pacific Plate slab subduction. We show the 2012 Aug. 14 earthquake with a vertical line, and we can see further landward acceleration synchronized with this earthquake.

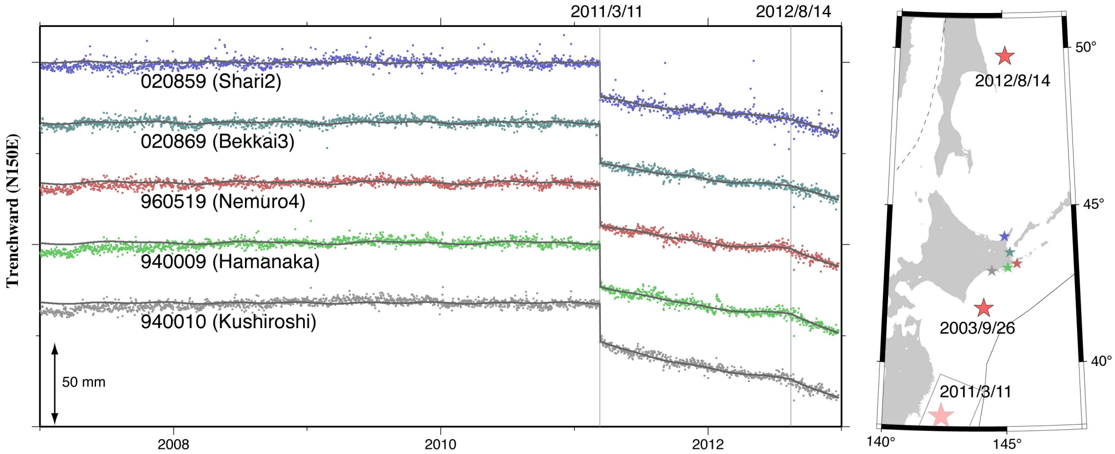
A deep earthquake with a down-dip compression mechanism occurring near the lower end of the slab would relax the increased edge resistance to a certain extent. This would reduce the up-dip force just like an interplate earthquake does, and may accelerate the subduction causing an apparent increase of the slip deficit as seen in the figure. Here we propose the following scenario, (1) upper surface of the slab moved by a few tens of meters in the 2011 Tohoku-Oki earthquake, and the compressional stress generated within the down-sip side of the slab diffused down to the depth of 500 km against viscous resistance in the low viscosity channel on the slab surface, (2) increased down-dip compression near the slab edge slightly braked the accelerated subduction (as seen in the small decay of the landward velocity during the 1st half of 2012), and caused the 2012 deep earthquake, (3) relaxation of the down-dip compression diffused upward and recovered the fully accelerated state. In the presentation, we also present quantitative discussions of these processes.

(Figure caption)

Trenchward (N150E) movement of the five GPS stations in eastern Hokkaido after 2007.0. We de-trended the time series using the portion between 2008/1/1 and 2011/3/11. Enhanced coupling (negative trend) slightly decayed during the first 1.5 years, but the original accelerated rate resumed after the 2012 deep earthquake.

Keywords: Pacific Plate, acceleration, deep earthquake, GPS, crustal deformation, Hokkaido

SCG66-02 Room:201A Time:May 24 09:15-09:30



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

SCG66-03 Room:201A Time:May 24 09:30-09:45

Crustal movement associated with Nankaido earthquakes

Ichiro Nakanishi[1*]

[1]Dept. Geophysics Kyoto University

We analyzed historical documents on the Nankaido earthquakes to estimate the crustal movement associated with the earthquakes in the Shikoku region, southwestern Japan.

Keywords: Nankaido earthquakes, crustal movement, Shikoku region

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

SCG66-04 Room:201A Time:May 24 09:45-10:00

Marine terraces composed of the Ryukyu Group, Tokuno-shima island, induced mega earthquakes

Soichi Osozawa[1*], Hiroki Tanaka[2]

[1]Department of Earth Sciences, Graduate School of Science, Tohoku University, [2]Togane High School

The Quaternary Ryukyu Group in Tokuno-shima island is devided into the Itokina (1.5Ma), Kinoko (0.9Ma?), and Kametsu Formation(0.2 Ma???), and each constitutes marine terrace. The boundary of the Itokina and Kinoko formations are terrace cliff, and the latter abuts the former. The succession indicates successive subsidence, but three times major uplift is expected to form three terraces. The uplift should have associated major reverse faulting, mega earthquake, and tsunami, all of which occurred along the Ryukyu trench.

Keywords: Tokuno-shima island, Ryukyu Group, 1.5 Ma Itokina Formation and higher terrace, Kinoko Formation and middle terrace, Kanetsu Formation and lower terrace, subsidence by normal faulting, uplift by reverse faulting, associated mega earthquake

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

SCG66-05 Room:201A Time:May 24 10:00-10:15

Stress states and physical properties along the Nankai Trough plate boundary

Hiroko Kitajima[1*], Demian Saffer[2]

[1]National Institute of Advanced Industrial Science and Technology, [2]The Pennsylvania State University

Recent seismic reflection and ocean bottom seismometer (OBS) studies reveal broad regions of low seismic velocity along the megathrust plate boundary of the Nankai subduction zone offshore SW Japan. These low velocity zones (LVZs) extend to ~55 km from the trench, corresponding to depths of >~10 km below sea floor. Elevated pore pressure has been invoked as one potential cause of both the LVZs and very low frequency earthquakes (VLFE) in the outer forearc. Here, we estimate the in-situ pore fluid pressure and stress state within these LVZs by combining P-wave velocities (Vp) obtained from seismic reflection and OBS data with well-constrained empirical relations between (1) P-wave velocity and porosity; and (2) porosity and effective mean and differential stresses, defined by triaxial deformation tests on drill core samples of the incoming oceanic sediment. We used cores of Lower Shikoku Basin (LSB) hemipelagic mudstone (322-C0011B-19R-5, initial porosity of 43%), and Middle Shikoku Basin (MSB) tuffaceous sandstone (333-C0011D-51X-2, initial porosity of 46%) that have been recovered from IODP Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) Site C0011 (~20 km seaward from the deformation front). Samples were loaded under a range of different stress paths including isotropic loading, triaxial compression, and triaxial extension. During the tests, all pressures, axial displacement, and pore volume change were continuously monitored; and ultrasonic velocity and permeability were measured at regular intervals.

The relationship between P-wave velocity and porosity for both LSB mudstone and MSB sandstone is independent of stress path, and is well fit by an empirical function derived by Hoffman and Tobin [2004] for LSB sediments sampled by drilling along Muroto transect, located ~150 km southwest of the NanTroSEIZE study area. The MSB sandstone exhibits slightly higher P-wave velocity and higher permeability than LSB mudstone at a given porosity.

Based on our experimental results, and assuming that the sediments in the LVZs are at shear failure defined by a critical state stress condition, we estimate that effective vertical stress in the LVZ ranges from 15 MPa at 13 km landward of the trench, to 41 MPa at a distance of 55 km. The maximum horizontal effective stress ranges from 41-124 MPa over this region. Excess pore fluid pressure ranges from 15-81 MPa, corresponding to modified pore pressure ratios, lambda* of 0.44-0.73. If LVZ is composed dominantly of sandstones, both the effective vertical and horizontal stresses would be lower, and the excess pore pressure would be higher, with pore pressure ratios lambda* = 0.31-0.90. Our results suggest that the sediments have been loaded under poorly drained conditions, and that pore fluids support ?~53-91 % of the overburden stress along the base of the accretionary wedge across the outer forearc. The low effective stress should lead to a mechanically weak plate boundary, and is spatially correlated with well-located low-frequency earthquakes in the outer accretionary wedge. The heterogeneous distribution of inferred pore pressure also suggests that fluid sources and drainage are localized and possibly transient.

Keywords: subduction zone, IODP, NanTroSEIZE, pore pressure, low frequency earthquake

SCG66-06 Room:201A Time:May 24 10:15-10:30

Compressional deformation of the Philippine Sea plate estimated from the seismic activity below the Nankai trough

Masaru Nakano[1*], Shin'ichiro Kamiya[1], Takeshi Nakamura[1], Yoshiyuki Kaneda[1]

[1]JAMSTEC

Off the Kii peninsula, Dense Observation Network for Earthquake and Tsunami (DONET) has been developed by Japan Agency for Marine-Earth Science and Technology (JAMSTEC). In this study, we determined hypocenters off the Kii Peninsula around the Nankai trough using data obtained from DONET, and discuss about the tectonic background of the seismic activity.

We assumed a layered velocity structure for the hypocenter determination. The velocity structure is based on the investigation by the Research concerning Interaction between the Tokai, Tonankai and Nankai Earthquakes, a project of JAMSTEC (Nakamura et al., 2011). We picked P and S onsets manually and determined the initial hypocenter locations by using the method of Hirata and Matsuura (1987, hypomh). We then used the double-difference method (Waldhauser and Ellsworth, 2000) to obtain detailed hypocenter distribution. We analyzed data between January 2011 and end of October 2012.

The hypocenters distributed below the Nankai trough extending about 100 km along the trough axis and 50 km width, which area well overlaps with the aftershock distribution of the 2004 Off the Kii Peninsula earthquakes. The seismic activity can be distinctly separated into those in the oceanic crust and uppermost mantle. A few earthquakes were found in the sedimentary wedge. The activity in the crust can also be divided into several clusters: Cluster A, located in the northeast of the active area, aligns in the ENE-WSW, parallel to the trough axis. About 20 km south of this activity is Cluster B, trending in the NNE-SSW almost parallel to the trough axis. Southwest of these clusters, intensive seismicity trending in the NS is found (Cluster C), perpendicular to the trough axis. The activity in the uppermost mantle is aligned on a plane striking parallel to the trough axis and dipping to the southeast. We also found an activity distributed on a plane dipping to the northwest.

Southeast of Cluster B, the Zenisu ridge is located along the oceanward slope of the Nankai trough. This ridge is considered to be formed by the compressional deformation in the lithosphere of the subducting Philippine Sea plate. The existence of a thrust dipping to the northwest is estimated below the ridge (e.g. Nakanishi et al., 1998; Mazzotti et al., 2002). Mazzotti et al. (2002) tried to explain the distribution of earthquakes around this ridge by the Coulomb stress change due to a slip on the estimated thrust in the mantle. Northwest of the Zenisu ridge, the Paleo-Zenisu ridge is estimated to be subducted below the sedimentary wedge (e.g. Le Pichon et al., 1995). This ridge is also considered to be formed by the compressional deformation of the oceanic plate (e.g. Park et al., 2003). The Paleo-Zenisu ridge is estimated to extend to below the Kumano fore-arc basin (Park et al., 2003), corresponding to the present seismic activity (clusters A and B). Assuming a thrust in the uppermost mantle, the earthquake clusters A and B may correspond to the region of the Coulomb stress increase estimated by Mazzotti et al. (2002).

The present seismic activity infers the existence of a thrust dipping to the southeast in the lithosphere of the subducting Philippine Sea plate below the Paleo-Zenisu ridge. The thrust estimated below the Zenisu ridge dips to the northwest, on the other hand. The location of uplift caused by the thrust does not correspond to the Paleo-Zenisu ridge. Accordingly, the estimated thrust may not be related to the formation of the Paleo-Zenisu ridge. However, we would conclude that the compressional deformation of the Philippine Sea plate still continues; the 2004 earthquakes ruptured the oceanic crust and the seismic activity in the crust and uppermost mantle have been activated afterwards.

Keywords: Nankai trough, Ocean-bottom seismic observations, Paleo-Zenisu ridge

SCG66-07 Room:201A Time:May 24 10:30-10:45

Effects of surface erosion on fault activity in thrust-belts

Yasuhiro Yamada[1*], Masashi Nakatsukasa[1], Toshifumi Matsuoka[1]

[1]Graduate School of Engineering, Kyoto University

Thrust and fold-belts are uplifted by displacement of their internal thrusts, and the uplifted topography is commonly eroded. We investigate the effects of surface erosion by using analog model experiments and the distinct element numerical simulation. This study focused on the parameters that determine the amount of erosion due to 1) surface inclination and 2) inflection point of the surface inclination. Brief comparison to natural examples will also be presented.

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

SCG66-08 Room:201A Time:May 24 11:00-11:15

Roles of Stress and Pore Fluid Pressure in Triggering Aftershocks Following the 2011 Tohoku-oki Earthquake

Toshiko Terakawa[1*]

[1]Earthquake and Volcano Research Center, Graduate School of Environmental Studies, Nagoya University

The earthquake is a physical process releasing tectonically accumulated stress by shear faulting, controlled by Coulomb failure criterion. In order to understand earthquake generation, we need to know the fault strength as well as the tectonic stress state in the Earth's crust. In the present study we examined the roles of tectonic stress and pore fluid pressure in seismicity changes following the 2011 off the Pacific coast of Tohoku (Tohoku-oki) earthquake through the analysis of aftershocks based on the Coulomb failure criterion. Background tectonic stress fields in Northeast Japan are generally characterized by E-W compression. After the Tohoku-oki earthquake, as expected from decrease in the Coulomb failure function, seismicity in the upper crust of Northeast Japan decreased except some restricted regions, where we observed many aftershocks with unfavourable focal mechanisms to the background stress fields. Most aftershocks can be regarded as reactivation of pre-existing faults under the background tectonic stress field, because misfit angles between observed and expected slip vectors are within estimation errors. By mapping the focal mechanisms of aftershocks on the 3-D Mohr diagram region by region, we confirmed that the aftershocks occurred on optimally oriented faults in some regions but on misoriented faults in other regions. The aftershocks on optimally oriented faults indicate the increase in regional ambient fluid pressure caused by the flow of over-pressurized fluid from a deep reservoir. On the other hand, the aftershocks on misoriented faults, which cannot be attributed to coseismic stress rotation, indicate the increase in fault-confined fluid pressure relative to the ambient fluid pressure. The decrease in fault strength due to increase in pore fluid pressure is one of the physical mechanisms triggering aftershocks.

Keywords: stress, pore fluid pressure, aftershock, focal mechanism of a seismic event, Coulomb failure criterion

SCG66-09 Room:201A Time:May 24 11:15-11:30

Volcanic subsidence triggered by the 2011 Mw 9.0 Tohoku earthquake, Japan

Youichiro Takada[1*], FUKUSHIMA, Yo[1]

[1]DPRI, Kyoto University

The 2011 Mw 9.0 Tohoku earthquake induced an unprecedented level of seismic activity in eastern Honshu, Japan. How did the volcanoes really respond to the earthquake? Some volcanoes exhibited increased seismic activity, but little is known about the deformation of their edifices.

We performed interferometric synthetic aperture radar (InSAR) analysis using ALOS/PALSAR data acquired before and after the Tohoku earthquake, to investigate the local deformation around volcanoes in the eastern Honshu. The interferograms, after removing the coseismic and early postseismic signals of the Tohoku earthquake, showed subsidence in a few volcanic regions: around Mt. Akitakoma, Mt. Zao, Mt. Kurikoma, Mt. Azuma, and Mt. Nasu. The subsidence reached 5-15 cm and exhibited elliptical shapes with horizontal dimensions of 15-20 x 10-15 km elongated roughly in the direction perpendicular to the axis of maximum coseismic extension. A station of the Global Positioning System (GPS) Earth Observation Network (GEONET) was located within each of the Mt. Zao and Mt. Azuma subsidence areas; the displacement time-series obtained at these sites indicate abrupt surface subsidence whose amount is roughly consistent with the satellite radar observations.

Concentration of Late Cenozoic calderas, high-temperature thermal water, high heat flow data, and borehole sampling of very young and hot granite suggest presence of hot plutonic bodies beneath the subsided regions. We hypothesize that magmatic and surrounding hot rock complexes, having a magma reservoir at the center surrounded by hot pluton and thermally weakened rock, have very small viscosity as a whole and played a major role in the subsidence. Using a boundary element method, we modeled the weak region as a fluid-filled ellipsoid and investigated how it deforms in response to the stress changes given by the Tohoku earthquake. It was found that such ellipsoids having the longer horizontal axis of ~10-20 km and top depth of shallower than a few kilometers can reproduce the observed subsidence signals.

Similar subsidence signals were also observed at several volcanoes in central Chile in association with the 2010 Maule earthquake (Mw 8.8), indicating that such subsidence triggering is ubiquitous for active volcanic chains along subduction zones.

Keywords: 2011 Tohoku Earthquake, InSAR, GPS, volcano, induced subsidence

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

SCG66-10 Room:201A Time:May 24 11:30-11:45

Seismic attenuation structures beneath the Hokkaido corner: Arc-arc collision and its relation to M˜7 inland earthquakes

Saeko Kita[1*], Junichi Nakajima[2], Tomomi Okada[2], Akira Hasegawa[2], Kei Katsumata[3], Youichi Asano[1]

[1]NIED, [2]RCPEV, Tohoku University, [3]ISV, Hokkaido University

1. Introdution

In the Hokkaido corner, the Kuril forearc sliver collides with the northeastern Japan arc. Using data from the nationwide Kiban-network and a temporary seismic network, Kita et al. [2012, JGR] determined high resolution 3D seismic velocity structure beneath this area for deeper understanding the collision process between the Kuril and NE Japan forearcs. The results show that a broad low-V zone (crust material) with a total volume of 80 x 100 x 50 km^3 anomalously descends into the mantle wedge area at depths of 30-90 km west of the Hidaka main thrust. On the other hand, several high-velocity zones having velocity of mantle materials are distributed at depths of 10-35 km, being in contact with the eastern edge of this low-V zone. Two of boundaries of the high-V zones with the broad low-V zone correspond to the fault planes of the 1970 Mj 6.7 Hidaka and the 1982 Mj 7.1 Urakawa-oki earthquakes, respectively. Inland micro-earthquakes also occur in the low-V zone at depths of -80 km. Kita et al. [2012, AGU fall meeting] estimated 3D seismic attenuation structure beneath the Hokkaido corner, but data used in that study are only from the Kiban-network. In this study, we estimated a detailed seismic attenuation structure by integrating data from the Kiban-network and those from the temporary seismic network operated by Katsumata et al. [2002], and compared it with the seismic velocity image previously obtained by Kita et al. [2012, JGR].

2. Data and method

We applied the method of Hada et al. [2011] to waveform data obtained from the Kiban network and the dense temporary seismic network. We estimated corner frequency for each earthquake by applying the spectral ratio method to the coda wave part [e.g. Somei, 2010; Wada, 2010; Mayeda et al., 2007]. We simultaneously determined values of $t*$ of earthquakes and amplitude level for the calculated spectra after determining a value of corner frequency. Then, seismic attenuation structure (Q structure) was imaged using $t*$ values and tomographic code of Zhao et al. [1992]. Ray paths were calculated by adopting the detailed 3-D seismic velocity structure by Kita et al. [2012]. In the calculation, we also used the geometry of the Pacific plate precisely estimated by Kita et al. [2010, EPSL]. The study region is 41-45N, 140.5-146E, and a depth range of 0-200 km. We obtained 57,132 P-wave and 41,251 S-wave spectra from 4,952 events ($M>2.5$) that occurred in the period from Oct. 2006 to Dec. 2011 (JMA catalog) and Aug. 1999 to Apr. 2001 (Katsumata et al., 2002). The number of stations is 353. Horizontal and vertical grid nodes were set with a spacing of 0.10-0.3 degree and 10-30 km, respectively.

3. Result

Estimated corner frequencies for earthquakes roughly obey cube-root scaling with seismic moment, stress drop being 0.1-10 MPa. In the Hokkaido corner, obtained image of seismic attenuation structure generally has the same anomalous structure as the detailed seismic velocity structure by Kita et al. [2012]; A broad low-Qp zone are located at depths of 0-60 km beneath the western area of the Hidaka main thrust, whereas the eastern area of it (Kuril forearc) has very high-Qp values. The low-Q zone almost coincides to the low-V zone in the collision zone found by Kita et al. [2012]. The fault planes of the 1970 M7.1and the 1982 M6.7 earthquakes are respectively located at the eastern edge of the low-Qp zone. Those tendencies in the image of Qp are also confirmed in the image of Qs. Western portion of the low-Qp zone has relatively lower Qp values, where inland type deep micro-seismicity is active. These results suggest that the occurrence of anomalous deep inland earthquakes in this region is related with spatial distribution of hydrous minerals or fluids.

Keywords: Seismic attenuation structure, Arc-arc junction, the 1970 M7.1 Hidaka earthquake, the 1982 M6.7 Urakawa-oki earthquake

SCG66-11 Room:201A Time:May 24 11:45-12:00

The crustal viscosity structure beneath the North Anatolian Fault Zone deduced from post- and inter-seismic deformation

Tadashi Yamasaki[1*], WRIGHT, Tim J.[1], HOUSEMAN, Gregory A.[1]

[1]University of Leeds, United Kingdom

The evolution of crustal stress during the earthquake cycle is controlled by visco-elastic relaxation in the lower and middle crust. Crustal viscosity, however, is a rather poorly constrained property. This study, based on 3D finite element calculations, describes the response of linear Maxwell visco-elastic models to periodic strike-slip faulting events in the presence of a constant far-field loading process, providing constraints on the actual variation of viscosity in the crust beneath the North Anatolian Fault Zone (NAFZ) from observed post- and inter-seismic surface displacement rates. The ratio of Maxwell relaxation time to earthquake cycle period is the principal controlling-factor of the system, though viscosity variation within the crust implies a wide spectrum of relaxation times in the system. Geodetic observations along the western NAFZ before and after the 1999 Izmit (17 August, Mw = 7.5) and Duzce (12 November, Mw = 7.2) earthquakes show that: (1) before an earthquake, the surface displacement rate gradient within a zone about 40 km wide is greater by a factor of about 2 than the gradient further afield, and (2) after an earthquake, surface displacement rates near the fault are greater, by a factor of 4 or so, than the estimated long-term displacement rates. Our numerical experiments find that (1) any model with a uniform viscosity (UNV) beneath an elastic lid is unable to explain these observations, (2) models with a depth-dependent viscosity (DDV) beneath an elastic lid might potentially satisfy the observations, but the wavelength of the strike-perpendicular post-seismic displacement profile does not fit well, and (3) models with laterally varying viscosity, including a localised weak zone (LWZ) beneath the faulted elastic lid, can best explain the observations, if the weakened and non-weakened domains have viscosities for which Maxwell relaxation times are significantly shorter and longer than the earthquake cycle period, respectively, and the spatial distribution of the surface velocities constrain the width and thickness of the LWZ. Several physical processes can be considered as possible explanations for why a LWZ should be present beneath a major fault like the North Anatolian, including: (1) non-Newtonian viscosity, (2) thermal dissipation, (3) grain-size reduction, and (4) pore fluid partial pressures. Explaining the origin of the weak zone may require a detailed multi-disciplinary study of the tectonic history of the North Anatolian Fault system.

Keywords: Earthquake cycle, Visco-elastic relaxation, Crustal viscosity structure, North Anatolian Fault Zone

SCG66-12 Room:201A Time:May 24 12:00-12:15

Geological meaning of residual velocity fields in GPS strain data inversion

Mitsuhiro Matsu'ura[1]*, Akemi Noda[2]

[1]Institute of Statistical Mathematics, [2]Kozo Keikaku Engineering Inc.

Recently, we developed an inversion method to estimate unbiased interseismic slip-deficit rates at plate interfaces from observed GPS velocity data with an elastic dislocation model [1]. Observed GPS data always include rigid block translation and rotations, which cannot be explained by the elastic dislocation model. So, in this method, first we remove the rigid block translation and rotations by transforming the velocity data into the average strain rates of triangle elements composed of adjacent GPS stations, and then invert the strain rates with a unified Bayesian inversion formula [2]. We applied the method of GPS strain-rate data inversion to interseismic GPS velocity data (1996-2000) in the Kanto region, central Japan, and obtained unbiased slip-deficit rate distribution on the North American-Philippine Sea and Philippine Sea-Pacific plate interfaces. In the inversion of strain-rate data, unlike in the direct inversion of velocity data, the obtained slip-deficit rate distribution does not always explain the observed GPS velocity data well, because they will include some rigid block translation and rotations. In the present analysis, we found significant residual velocities, which should not be explained by interseismic slip deficit at plate interfaces. From theoretical consideration to rotation tensor [1], we may ascribe the residual velocities mainly to rigid body translation and rotation of tectonic blocks; that is, the south-southeastward translation of the Izu microplate, which suggests plate convergence at the incipient subduction boundaries southeast off the Izu peninsula [3], the anticlockwise rotation of the south Kanto block, and the clockwise rotation of the Tokai block.

References

[1] Noda, A., C. Hashimoto, Y. Fukahata & M. Matsu'ura (2013), Interseismic GPS strain data inversion to estimate slip-deficit rates at plate interfaces: application to the Kanto region, central Japan, Geophys. J. Int., doi:10.1093/gji/ggs129.

[2] Matsu'ura, M., A. Noda & Y. Fukahata (2007), Geodetic data inversion based on Bayesian formulation with direct and indirect prior information, Geophys. J. Int., 171, 1342-1351.

[3] Taira, A., K.T. Pickering, B.F. Windley & W. Soh (1992), Accretion of Japanese Island arcs and implications for the origin of Archean greenstone belts, Tectonics, 11, 1224-1244.

Keywords: GPS data, strain data inversion, residual velocity fields, rigid block motion, Izu microplate