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

SCG72-01 Room:103 Time:May 22 14:30-14:45

Permeability anisotropy of serpentinite and fluid pathway in subduction zone

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Subduction zones are the only sites where water is transported into the Earth's deep interior. Water that is transported into the mantle affects the physical properties of mantle rocks, including their melting temperature and mechanical strength; consequently, the presence of water is believed to influence arc volcanism and seismicity. Permeability is a key parameter in controlling fluid flow in a mantle wedge. Although the fluid released into the wedge is generally believed to ascend under buoyancy, it is possible that fluid movement is influenced by anisotropic permeability in localized shear zones. The mantle rocks at the plate interface of a subducting slab are subjected to non-coaxial stress and commonly develop a strong foliation. Indeed, the existence of foliated serpentinite is indicated by strong seismic anisotropy in the forearc mantle wedge (e.g., Katayama et al. 2009). Therefore, fluid pathways in the mantle wedge may be controlled by the preferred orientation of highly anisotropic minerals. In this symposium, we present results of permeability experiments of highly foliated serpentinites (Kawano et al. 2011).

We used an intra-vessel deformation and fluid flow apparatus housed at Hiroshima University. Permeability measurements were performed using a steady-state flow, which consists of generating a known pore-pressure gradient across the specimen and measuring the flow rate. Under low confining pressure, all the experiments show similar permeability, in the order of 10-19 m2. However, permeability anisotropy appears under high confining pressures, with the specimens oriented parallel to the foliation having higher permeability than those oriented normal to the foliation. At a confining pressure of 50 MPa, the difference in permeability between the samples with contrasting orientations reaches several orders of magnitude, possibly reflecting the pore tortuosity of the highly sheared serpentinite.

The present experimental data show that the highly foliated serpentinites have a marked permeability anisotropy: consequently, fluid migration is strongly influenced by the orientation of the foliation in the mantle wedge. Serpentine forms in the mantle wedge because of the infiltration of water expelled from the subducting plate, above which deformation is concentrated in a relatively thin layer (e.g., Hilairet and Reynard 2009). In such a case, the water released from the subducting plate migrates along the plate interface. The total flux of fluid expelled from the subducting plate would be expected to result in a thick layer of serpentinized mantle, if the water migrates vertically in the mantle wedge. However, geophysical observations, including seismic tomography and reflection data, have shown that the serpentinized layer is limited to a narrow zone above the subducting plate. These data are consistent with our hypothesis that fluid tends to migrate within the highly sheared serpentinite layer, along the plate interface, rather than vertically upward. The migrating water along the subducting plate boundary may accumulate at the corner of the wedge, which might trigger low-frequency earthquakes due to a pore pressure build-up at the boundary.

Keywords: permeability, serpentinite, fluid migration, subduction zone

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SCG72-02 Room:103 Time:May 22 14:45-15:00

Earthquakes in subduction zones: An important role of aqueous fluids in earthquake generation

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Recent investigations have shown that slab-origin aqueous fluids play an important role in generation of three main types of earthquakes in subduction zones. Studies on spatial distribution of intraslab earthquakes and tomographic imagings of seismic velocity structure within the Pacific slab provide evidence which supports the dehydration embrittlement hypothesis for generation of intermediate-depth intraslab earthquakes. Investigations of detailed seismic velocity structure in and around the plate boundary zones suggest that interplate coupling is mainly controlled by fluid overpressure there or serpentinization of the mantle wedge right above. Seismic tomography studies show the existence of inclined sheet-like seismic low-velocity zones in the mantle wedge not only in Tohoku but also in other areas in Japan, which perhaps correspond to the upwelling flow portion of the subduction-induced convection system. The upwelling flows reach the Moho right beneath the volcanic areas, suggesting that those volcanic areas are formed by the upwelling flows. Aqueous fluids derived from the slab are probably transported upward through the upwelling flows to reach the arc crust, where they might work to weaken the surrounding crustal rocks and finally cause shallow inland earthquakes.

Generation of the 2011 Tohoku-oki earthquake and its induced seismic activities also seem to be closely related with aqueous fluids. We observed a clear temporal change in stress field near the source area after the earthquake which shows nearly complete stress drop by the earthquake, suggesting that the plate interface is very weak. Temporal change in stress field after the earthquake is also observed for inland areas, suggesting that faults for inland earthquakes are weak as well. The weak faults are probably caused by overpressured fluids. Tomographic imagings in the source area of a large (M7.1) intermediate-depth intraslab aftershock provide evidence for reactivation of a buried hydrated fault in the Pacific slab.

These observations suggest that aqueous fluids expelled from the subducted slab play an important role in the generation of three main types of earthquakes in subduction zones.

Keywords: Subduction zone, aqueous fluids, interplate earthquake, intraslab earthquake, shallow inland earthquake

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SCG72-03 Room:103 Time:May 22 15:00-15:15

Runaway slip to the trench due to rupture of highly pressurized megathrust, Tsunamigenesis of the 2011 Tohoku earthquake

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The gigantic 2011, March 11 Mw 9 Tohoku earthquake is examined from the viewpoint of the pre-seismic forearc structure, the seismic reflection properties of amegathrust around the usual up-dip limit of the seismogenic zone, the thermal state of a shallow subduction zone, and the dehydration of underthrust sediments. At the Japan Trench the Pacific Plate is subducting westward beneath the northeast Japan at a dip angle of 4.6. The middle and lower slopes dip eastward at angles of ˜2.5 and ˜8.0, respectively. The forearc prism beneath the middle and lower slopes is inferred to be in extensionally and compressively critical states, respectively, based on the presence of clear internal deformation features and on the occurrence of aftershock earthquakes. The rapid uplift of the forearc that caused the 2011 Tohoku tsunami may have been associated with this internal deformation of the prism. The critical state of the prism indicates that the effective basal friction of the plate boundary megathrust is $<$0.03 for the middle prism and $>$0.08 for the lower prism. The megathrust, especially under the middle slope, is characterized by a prominent reflector with negative polarity; i.e., a landward-increasing wave amplitude. This observation suggests that the megathrust hosts highly pressurized fluids. Underthrust sediments in this part of the Japan Trench are dominated by pelagic and siliceous vitric diatomaceous silt with clay. The dehydration kinetics of opal-A to quartz, the clay transformation of smectite?illite, and the thermal structure of the Japan Trench suggest that maximum dehydration of the sediments would take place at 50?60 km horizontally from the deformation front, where the temperature along the megathrust is 100?120. The zone of maximum dehydration coincides with the prominent seismic reflector that has negative polarity. We hypothesize a possible free slip along thisportion of the megathrust during the 2011 Tohoku earthquake, caused by anomalously high fluid pressure resulting from fluid accumulation over centuries.

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SCG72-04 Room:103 Time:May 22 15:30-15:45

Diagenesis and dehydration of subducting oceanic crust within seismogenic subduction zones

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Seismogenic plate-boundary faults at accretionary margins may lie within or close to the subducting oceanic crust, composed of basaltic rocks, in contact with the overriding plate of a lithified accretionary prism (Kimura and Ludden, 1995; Park et al., 2001; Matsumura et al., 2003). Therefore, diagenesis and dehydration of the oceanic crust within the seismogenic zone (normally defined as a temperature condition from ˜100-150 to 350-450^{o}C; Hyndman et al., 1993) is supposed to have a great influence on the interplate mechanical behaviors where great earthquakes occur. Our previous work showed that basaltic basement at the top of the oceanic crust is remarkably hydrated prior to reaching the trench axis, and pointed out a possibility to be a significant source of fluid in the seismogenic zone (Kameda et al., 2011). The aim of this work is to provide complementary dataset on the state and pathways of diagenesis in the subducting oceanic crust to verify the argument presented in the previous paper. In particular our focus is on a more validate quantification of the dehydration processes within the seismogenic zone. In this work, we analyzed 5 pillow basalt samples exposed in the Cretaceous to Tertiary accretionary complex, the Shimanto Belt, southwest Japan. Based on the vitrinite reflectance measurement of terrigenous sediments accompanied by these rocks, they are estimated to have been subjected to burial diagenenesis at 150-300 ^{o}C. X-ray diffraction (XRD) analyses of the bulk samples revealed that they contain ˜25wt% of hydrous clay minerals. Moreover, clay-fraction XRD exhibited a successive conversion of smectite (saponite) into chlorite as a function of diagenesis grade. In this talk, we will present an improved model of the dehydration behavior of subducting basaltic crust inferred from these data, and address its potential influence on the evolution and physical states of the seismogenic-plate boundary faults.

Keywords: seismogenic zone, dehydration, oceanic crust, saponite

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SCG72-05 Room:103 Time:May 22 15:45-16:00

10 years of ACORK: Continuous pressure from the decollement zone at Nankai Trough off Muroto

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During the KR22-12 cruise, three dives were completed using ROV KAIKO onboard R/V KAIREI during Dec. 20-25, 2011, to retrieve pressure data and interstitial fluid samples from ACORKs at ODP Holes 808I and 1173B situated landward and seaward of the deformation front in the Nankai Trough off Muroto. With 3-year-long and a 4-year-long new data records from 808I and 1173B, respectively, we now have over 10-year-long continuous pressure records since June 2001 at both sites. Most of pressure data from multiple depths show systematic variations in pressure with depth, and in tidal signal amplitudes. Transient changes were observed at the time of several nearby earthquakes, including ones during the recent 3 to 4 years at the time of Mar. 11 Tohoku earthquake, followed by a long-lasting pressure change starting on Mar. 23, 2011.

Gas-tight fluid sampling operations were successfully carried out from the hydraulic port attached to the swellable packer inserted within the ACORK head. The swellable packer was set in order to isolate the decollement zone that lies roughly 20 m below the bottom of casing at 922 m below the seafloor. We observed shimmering water venting through the port, and the flow rate was measured using a ball-type flowmeter. Fluid samples looked muddy-colored, probably due to the stain from the casing steel. Geochemical as well as microbial analyses are planned as a post-cruise activity, and a full analysis of the relationship between the Tohoku earthquake and the pressure transients is underway.

Keywords: ACORK, Nankai Trough, pore pressure, decollement

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SCG72-06 Room:103 Time:May 22 16:00-16:15

Experimental demonstration of high-temperature fluid generation during coseicmic fault slip

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The generation of a high-temperature hydrous fluid by frictional heating crucially affects on the fault-slip behavior. Thermal pressurization is widely known dynamic weakening mechanism, by means of which fluid pressure generated by shear-related heating reduced the fault strength during seismic slip. In the case of Taiwan Chelungpu fault, anomaly of fluid-mobile trace elements (Sr, Cs, Rb and Li), and Sr isotope ratios was reported, and it was attributed to fluid-rock interaction at high temperature (>350C) and being an evidence that thermal pressurization occurred during 1999 earthquake. However, the anomaly in trace elements and isotopes have not been demonstrated and verified experimentally. So, we here performed high-velocity frictional experiments on simulated fault gouge under wet condition, and analyzed the trace elements and Sr isotope of the samples after the experiments with an inductively coupled plasma spectrometer.

We used a rotary shear testing apparatus at the Kochi Core Center. The pore pressure and normal stress can be controlled during experiments. A series of experiments was performed at a 14-15 MPa normal stress, 2-5 MPa pore pressure and 0.2-0.4 m/s slip velocity with several displacements between 14.7-29.3 m. With increasing slip, the shear stress decreased, and the temperature reached at 300C. We found distinct depletion of Li in the sample experienced 300C. Because Li is known as fluid-mobile element and significantly mobilizes into fluids above 300C, the change of Li concentration in the sample indicate fluid-rock interactions at high temperatures. Therefore, our experimental results verify that trace element compositions can be good proxy for generation of high-temperature fluid during coseismic slip.

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SCG72-07 Room:103 Time:May 22 16:15-16:30

Along-trench variation of the water contents within the incoming plate offshore north-eastern Japan

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The dehydration process and the expelled water from the subducting oceanic plate are expected to affect various subduction zone processes, including the arc volcanism, generation of the intermediate-depth earthquakes and the regional variation in the seismic coupling of plate interface. To better understand these subduction zone dynamics, it is essential to clarify the amount of water that is being subducted within the incoming oceanic plate into the subduction zone.

In the northern Japan trench subduction zone, a number of great interplate earthquakes, such as the 2011 Mw 9.0 Tohoku-oki earthquakes, have repeatedly occurred. However, the distribution of rupture zones of these interplate earthquakes shows distinct regional variations. It has been suggested that the along-trench variation in the distribution of large interplate earthquakes are well correlated with the along-trench variation in the outer trench seafloor roughness. Recently, seismic structure studies in the middle and south America trench have suggested that the seafloor roughness including seamounts and bending-related faulting is closely associated with the oceanic plate hydration. Thus, there is a possibility that the along-trench variation of the large interplate earthquakes in the northern Japan trench subduction zone is associated with the amount of water that is being subducted within the incoming plate.

In 2010, to clarify the regional variation in the seismic structure and regional variation in the amount of water containing within the incoming plate, we conducted an extensive wide-angle seismic reflection and refraction survey along a trench-parallel profile using OBS and air-guns. We obtained P-wave and S-wave velocity structure models by traveltime inversion techniques and a seismic reflection section by Prestack depth migration. All the obtained seismic structure models including Vp/Vs show significant along-trench variations. As expected, in the region where the seafloor bathymetry is rough (between 38 and 39 degrees north), seismic velocities within the oceanic crust and oceanic mantle are low and Vp/Vs is high. This suggests that water infiltration and/or the hydration of the incoming oceanic plate is high in the region where the seafloor is rough, and indicates that the amount of water that is being subducted within the incoming plate varies significantly along trench axis in this region.

Keywords: outer rise, seismic velocity, water contents, hydration, wide-angle seismic survey, OBS

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SCG72-08 Room:103 Time:May 22 16:30-16:45

Estimation of velocity structure in the oceanic crust of the Pacific slab beneath northeast Japan form PS converted wave

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Seismic tomography (e.g. Nakajima et al., 2009) and receiver function analysis (Kawakatsu and Watada, 2007) have revealed the existence of the low-velocity oceanic crust at the uppermost part of the Pacific slab beneath the northeastern Japan arc. However, these methods cannot estimate a detailed spatial variation in seismic velocity in the oceanic crust.

It is known that P-to-S converted phases at the plate interface are often observed in seismograms of intraslab earthquakes. Matsuzawa et al. (1986) examined arrival times and amplitudes of PS converted phases and suggested the existence of a low-velocity layer at the top of the slab down to a depth of at least 150 km. Here we estimate P-wave velocity structure in the oceanic crust using PS converted waves recorded at a nation-side seismic network.

In this study, we identify PS converted waves using theoretical travel times and particle motions of the waveforms, and read arrival times of the waves. We then estimate P wave velocity in the oceanic crust assuming the geometry of the Pacific plate and seismic velocities in the mantle wedge, arc crust and descending plate. As a result, we obtain P-wave velocity structure of 6.5-7.0 km/s in the fore-arc side and of 7.5-8.5 km/s in the back-arc side. We consider that these velocity variations are related to phase transition in the oceanic crust.

Keywords: PS converted wave, oceanic crust, Pacific slab

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SCG72-09 Room:103 Time:May 22 16:45-17:00

Fluids dehydrated from the subducting oceanic crust and non-volcanic seismic swarms

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A non-volcanic seismic swarm is often assumed to be tied to fluid movements, based on earthquake mi-grations obeying a diffusion equation. However, seismological observations that relate to the presence and driving force of fluids are not well documented. One of the most intensive non-volcanic seismic swarms in Japan is located in the Wakayama district, SW Japan, and quite distant from the present volcanic front.

It is important to fully describe the crustal heterogeneity originating in crustal fluids. We have deployed a very dense seismic array with a length of about 100 km at the western edge of the Kii Peninsula. The dense seismic observations were conducted from December in 2010 to June in 2011. The linear array consists of 86 seismometers with 1 Hz natural fre-quency, those continuously recorded three-component signals. Both P- and S-wave arrival times from local earthquakes including some low-frequency earth-quakes (LFEs) were manually picked from waveforms observed by both dense temporary stations and per-manent stations. The dense and well-covered ray-paths from local and teleseismic events afford us precious opportunities to investigate the fine-scale seismic structures.

The most striking feature of the fine seismic image is low-velocities with low Poisson ratios beneath the seismic swarm region. This low-velocity feature is also supported by the receiver functions. In addition, the corner of mantle wedge is characterized as low veloci-ty, leading to an inverted inland Moho at depth of about 30 km. This low velocity mantle seems to ex-tend to deeper depths.

At depths shallower than 40 km, a depth-section of receiver functions shows that the oceanic crust, of which the top and bottom (plate interface and oceanic Moho) are outlined by strong negative and positive amplitudes, respectively, is subducting at a dip angle of approximately 15-degree. In contrast, the polarity of the plate interface changes from negative to positive at depths greater than 50 km. The dip-angle of the oceanic crust increases with depth. We interpret the transitions of the polarity as indicating the onset of eclogitization of the oceanic crust. The subducting oceanic crust beneath LFEs is characterized by low-velocities and high Poisson ratios, which are commonly observed at Tokai or Shikoku regions.

We propose that fluids dehydrated from the sub-ducting oceanic crust could infiltrate into the mantle wedge and crust, leading up to the intensive non-volcanic seismic swarms in Wakayama and high-helium isotopes widely observed in the Kii Pen-insula.

Keywords: seismic swarm, crustal fluid, non-volcanic, velocity structure, receiver function, dehydration

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SCG72-P01 Room:Convention Hall Time:May 22 17:15-18:30

Fluid chemistry of the fault propataion zone ?fluid inclusion analysis from the Lishan fault, Taiwan-

OKAMOTO, Kazuaki[1*], Chihiro Iijima[1], KUROSAWA, Masanori[2], Yu-Chang Chan[3], Masaru Terabayashi[4]

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Liberation of CO2-rich gas from fluid preserved in the fault propagation zone would be important phenomena in the earthquake and aftershock process. We have detected that injected fluid in link thrust would cause fault propagation and fault lubrication due to vapor-separation [1]. Recently, one of the authors, Yu-Chang Chan found unusual quartz vein on the great link-thrust, Lishan fault, in Taiwan orogenic belt [1]. The quartz vein is spherical shape and is composed of large crystals and surrounding milky fine-grained crystals. The transparent quartz grains contain large primary fluid inclusions over 100 microns in diameters. The fluid inclusion is classified as two phase, vapor phase and three phase inclusion. Homogenization temperature is 260 oC and NaCl wt% estimated from freezing T, is 7.41. In order to measure fluid chemistry, PIXE analysis was done at Tsukuba University. Analytical procedure is shown in [2]. The result is summarized as follows. Br/Cr ratio is lower than that in seawater. Ti, Cr, and Ni contents are high, suggesting that fluid is related to magma activity beneath the fault. Vapor-phase inclusion contains considerable amount of metal elements (Ti, Zn, Ge, Mn, Ca, Fe, Pb, Rb, and Cu) as well as K, and Br. Fractionation differences between the vapor and the fluid would be useful tool to detect vapor separation due to fault propagation.

References
[1] Chan, Y. et al., Terra Nova 17, 439-499 (2005)
[2] Kurosawa M. et al.,Island Arc, 19, 17-29 (2010)

Keywords: Lishan Fault, Taiwan, Accretionary thrust, Quartz vein, fluid inclusion, PIXE analysis, gas separation due to fault rupture

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SCG72-P02 Room:Convention Hall Time:May 22 17:15-18:30

Spatial distributions of mantle helium and deep-seated carbon in northeastern Japan

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On the basis of a progressed seismograph network in recent years, geophysical studies indicate detailed structure and transportation paths of fluids in subduction zone, northeastern Japan (Hasegawa et al., 2005). The presence of fluid is presumed by the seismic velocity anomalies, however, it is difficult to detect directly what kind of fluid is upwelling from geophysical studies. We focus on showing an outline of the geographical distribution of mantle helium and deep-seated carbon obtained from hot spring water/gases in northeastern Japan.

We have collected water/gases samples from hot springs throughout the northeastern Japan and analysed the helium isotope ratio (^{3}He/^{4}He) and the deep-seated carbon concentration (Cds) both of which are good indicators to distinguish the origin of fluid. Helium-3 is originated from mantle and Cds is considered to be derived from the slab.

Spatial variation clearly showed the high ^{3}He/^{4}He ratio and Cds in volcanic front and back-arc region in northeastern Japan. However, the distribution has regional variation. The geographical distributions of ^{3}He/^{4}He ratio and Cds observed at the surface are found to be similar to that of seismic low-velocity zone of wedge mantle. The distribution of seismic low-velocity zone is thought to be resulted in the existence of fluids, partial melts or mantle diapirs. Therefore, the similarity of the distributions may represent that there are some fluid path for the upwelling the helium and carbon species to the surface from the underlying seismic low-velocity zone.

Keywords: helium isotope ratio, deep-seated carbon, northeastern Japan, fluid

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Lower crustal heterogeneity beneath the northeast Japan

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Numerous crustal earthquakes occurred beneath the northeast Honshu arc after the 2011 Tohoku-Oki M9 earthquake. However, crustal earthquakes following the 2011 Tohoku-Oki M9 earthquake is not homogeneously distributed throughout the northeast Honshu arc. For example, seismicity rate increase around Iwaki after the 2011 Tohoku-Oki M9 earthquake, and the 11 April 2011 Mj=7.0 Iwaki earthquake, which is one of the biggest crustal earthquakes, produced over 10km of normal faulting along Shionodaira fault in the Gosaisho metamorphic rocks (the eastern half of the Abukuma metamorphic belt).

Because mineral chemistry and rock composition are important factors to control rheological strength of the arc crust, inhomogeneous distribution of the crustal earthquakes is expected to reflect deep crustal inhomogeneity, Our previous study of petrological crustal structure model of the northeast Honshu arc showed that; (1) the high-Vp and Vs regions beneath the Tobishima Basin consist of hornblende-pyroxene gabbro, (2) hornblende gabbro is a predominant rock type beneath the Dewa Hillsand Ou Backbone Range, (3) the low-velocity anomalies beneath the active volcano areas may be caused by the existence of partial melts of hornblende gabbro, and (4) the low-Vp and high-Vs regions beneath the Kitakami Mountains consist of quartz plagioclase-bearing rocks. The study demonstrated that the heterogeneity of seismic velocity in the lower crust of the northeast Japan arc reflects variations in rock composition and temperature that are related to the regional geological history. However this model doesn’t include a key geological event ”Cretaceous left-lateral shearing”. In order to evaluate the postseismic crustal deformation around Iwaki, we have to take into account the Cretaceous left-lateral shearing in crust and mantle of the NE japan.

Keywords: crust, island arc, Tohoku, seismic velocity, elastic wave velocity

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Runaway slip to the trench due to rupture of highly pressurized megathrust beneath the middle trench slope

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In plate subduction zone, enormous earthquakes occur repeatedly on the plate boundary, which is facing surface between subducting sediments and basal rocks. The subducting rocks have been presumed to supply water to the plate boundary during subducting, which has much effect on deformation processes and earthquakes in the subduction zone. To clarify the relation between dehydration, deformation and earthquakes along subduction zone, we discussed diagenesis and deformation processes of ribbon cherts embedded in a Jurassic accretionary complex, central Japan, and evaluated the dehydration region in the Japan Trench through numerical simulation.

The diagenesis and deformation processes of ribbon cherts were investigated in detail to gain a better understanding of the mechanical behavior of the plate boundary at depth in cold subduction zones. The analyzed cherts record two stages of deformation: (1) map- to outcrop-scale ductile folding, and (2) subsequent brittle faulting. The ductile deformation was facilitated by silica dehydration?precipitation, and is represented by multiple stages of vein networks. The folds are cut by brittle faults, indicating lithification and the concurrent mechanical transition from ductile to brittle behavior. Slip zones along the faults are typically filled with brecciated chert in a chlorite matrix. Geothermometry analysis of the matrix chlorite suggests that faulting occurred following the completion of opal-CT to quartz transition reaction. This is also confirmed by the kinetic simulation of silica conversion reactions. The results suggest that ductile deformation of thick pelagic deposits with abundant fluids results in an aseismic plate boundary, whereas chemical diagenesis of the deposits, producing crystalline cherts, results in strong interplate coupling in cold subduction zones such as the Japan Trench.

Based on the upper results and discussion, the gigantic 2011, March 11 Mw 9 Tohoku earthquake is examined from the viewpoint of the pre-seismic forearc structure, the seismic reflection properties of a megathrust around the usual up-dip limit of the seismogenic zone, the thermal state of a shallow subduction zone, and the dehydration of underthrust sediments.At the Japan Trench the Pacific Plate is subducting westward beneath the northeast Japan at a dip angle of 4.6 deg. The middle and lower slopes dip eastward at angles of ˜2.5 and ˜8.0 deg, respectively. The forearc prism beneath the middle and lower slopes is inferred to be in extensionally and compressively critical states, respectively, based on the presence of clear internal deformation features and on the occurrence of aftershock earthquakes. The rapid uplift of the forearc that caused the 2011 Tohoku tsunami may have been associated with this internal deformation of the prism. The critical state of the prism indicates that the effective basal friction (mub') of the plate boundary megathrust is $<$0.03 for the middle prism and $>$0.08 for the lower prism. The megathrust, especially under the middle slope, is characterized by a prominent reflector with negative polarity; i.e., a landward-increasing wave amplitude. This observation suggests that the megathrust hosts highly pressurized fluids. Underthrust sediments in this part of the Japan Trench are dominated by pelagic and siliceous vitric diatomaceous silt with clay. The dehydration kinetics of opal-A to quartz, the clay transformation of smectite?illite, and the thermal structure of the Japan Trench suggest that maximum dehydration of the sediments would take place at 50?60 km horizontally from the deformation front, where the temperature along the megathrust is 100?120C. The zone of maximum dehydration coincides with the prominent seismic reflector that has negative polarity. We hypothesize a possible free slip along this portion of the megathrust during the 2011 Tohoku earthquake, caused by anomalously high fluid pressure resulting from fluid accumulation over centuries.

Keywords: underthrust, sediment, dehydration, excess pore pressure

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Source, sink and pathway of fluid dehydration from pelagic siliceous sediments in cold subduction zone

HINA, Shoko[1], YAMAGUCHI, Asuka[1], HAMADA, Yohei[1*], KAMEDA, Jun[1], HAMAHASHI, Mari[1], KUWATANI, Tatsu[2], KIMURA, Gaku[1]

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The fluid existing at plate boundaries in subduction zone makes a strong effect on seismicity and fault slip along the plate boundary megathrusts. Seismogenesisis controlled mainly by temperature which ranges from ˜150 degrees C to 350-450 degrees C (Hyndman and Wang, 1993; Hyndman et al., 1995, 1997; Oleskevich et al., 1999). Additionary, the dehydration at shallow zones cooler than ˜150 degrees C along plate boundaries is also important to understand the propagation of fault slip occurring at further deep seismogenic zones.In this study, we firstly evaluated the amount of dehydration from siliceous sediment on subducting plates. Siliceous sediments might be thick and abundant because of long-period exposure to the ocean far from the continents in the case of old oceanic plates, for example, the Japan Trench. The diagenesis and dehydration of siliceous sediments are calculated quantitatively introducing reaction kinetics and temperature profile models of the Japan Trench, a cold subduction zone, where the siliceous sediments dominantly subduct. As a result, structured water within silica minerals is released through the diagenesis much as ˜160 g/m2/year along shallow plate boundary (˜5-10 km depth), where the temperature is ˜100 degrees C.Second, we performed parameter sensitivity analyses of silica diagenesis to explain the depth variation of dehydration zone in above calculation and to evaluate the possible range of it. The analyses revealed that the dehydration from silica can proceed at various temperature ranges (80-120 degrees C) depending on subducting parameters. The most effective parameter is temperature gradient, gamma, and result dispersion in above estimation can be explained by the variation of it.To discover evidence of dynamic dehydration from silica diagenesis and to connect dehydrated water and rock deformation, we thirdly performed geological research in the Inuyama area, Mino-Tamba Belt, Jurassic accretionary complex in Central Japan as an on-land analog of the sediments on the old oceanic plates. As well as white chert recording focused fluid flow and silica precipitation, we investigated the pressure solution seam (PSS) evolved inside of a red chert and conducted element analyses using Electron Probe Micro Analyses (EPMA). Isocon method was introduced to the results and revealed that ˜530 vol% of silica had escaped from pressure solution seam. This result supports our calculation results and suggests the existence of abundant water in subducting sediments on the old oceanic crusts, although this estimation is too large to give a sufficient explanation from silica diagenesis. There are some ways to explain this problem, and we finally discussed the possible deformation mechanism depending on the diagenesis and dehydration of siliceous sediments with depth and temperature.

Keywords: siliceous sediment, subduction zone, chert, dehydration, deformation

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Imaging of the fluid injection zone at the Nojima-fault: Reanalysis of 2003 Awaji Island water injection experiment

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Monitoring the physical states of seismogenic zone is one of the most demanded subjects in seismology. The attempt to monitor the underground fluid behavior by seismic ACROSS (Accurately Controlled Routinely Operated Signal System) has been continued by the research group of Nagoya University and other institutions. The air injection experiment in 100m depth in Awaji Island in 2011 showed clear image of injection zone by the time-reversal method (Kasahara et al., 2012). In order to compare the 2011 results and the previous water injection experiment in 2003, we reanalyzed the data obtained by the seismic ACROSS at Awaji Island in 2003 (Misu et al., 2003), to detect the influence of the water-injection experiments at the Nojima Fault.

The continuous observation was made for about five months in February to June, 2003, using two seismic ACROSS vibrators and two seismic arrays at about 300 m away from the source to NW and SWW, respectively. In the water injection from March 13 and March 23, 225 tons water in total with 4.5MPa was injected at 540 m depth of the 1,800 m borehole at 150 m distance of NNW of the source. Two ACROSS vibrators shared the frequency band and generated vibration in 10-22 Hz in total. Each seismic array comprised 10 seismometers shaping a cross with 10 m spacing.

By the previous analysis by Misu et al. (2003), no significant signal accompanied with the water injection was found in the temporal variation of travel times of S- and surface waves, which showed the obvious response to the rainfall. By the water flow simulation, we found the similarity of flow speed caused by rain falls and the observed S-wave travel-time changes (Kasahara et al., 2011.

In this study, we performed the time-reversal imaging using the differential waveforms between before and after the water injection, in order to examine the ability of detecting the area of influence by the water injection. As a result, the NS-oscillation of the time-reversal using the two arrays focuses around the borehole of the water injection. The array distribution seems not to be appropriate to this imaging and might be the reason for the other components not focusing around the injection point.

For the fluid migration into the subduction, we obtained the clear image of fluid layer by simulation (Tsuruga et al., 2010) and the current imaging method sing seismic ACROSS can be useful for the real-time monitoring physical state change along the future focal zones on subduction zone.

Keywords: Nojima Fault, Water injection experiment, ACROSS, Nojima Fault-zone Probe, Tiime lapse, 4D

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Upward fluid migration in free gas zone in the Kumano basin detected from the temperature logging at IODP Site C0009

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Temperature profiles are obtained in the Site C0009 during IODP 319, one of the expeditions of IODP NanTroSEIZE Stage 2, with multiple wireline logging. These temperature logs are from independent logging runs with different lapse time since after the end of mud circulation in the borehole. We estimated equilibrated temperature profile of the formation by the Horner plot method using multiple logging data. The thermal gradient obtained from equilibrated formation temperature is different between geological units; 31 K/km in Subunit IIIA, 17 K/km in Subunit IIIB, and 28 K/km in Unit IV. The smaller thermal gradient in Subunit IIIB may be the result from larger thermal conductivity, however the data from Site C0002 suggests that the thermal conductivity of Unit III and IV has similar values. The smaller thermal gradient in Subunit IIIB would be attributed to upward migration of fluid that is produced in the Kumano forearc basin sediments. The velocity of vertical flow in Subunit IIIB is estimated to be 9.2 x 10^{-9} m/s, which is comparable to velocity estimated in situ hydraulic property measurement. Examination of temperature gradient and apparent thermal conductivity from temperature logging and core thermal conductivity is one of the crucial tools to estimate the motion of fluid flow. Fluid flow can be estimated form the deviation of temperature profile from pure conductive model. This strategy is possibly capable for fluid flow with small velocity, which cannot be detected by direct measurement of fluid flow.

Keywords: Thermal structure, crustal fluid flow, forearc basin, deep drilling, well logging, NanTroSEIZE

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P and S Waves Traversing Beneath the Seto Inland Sea and the Shape of the Subducting Philippine Sea Plate

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By examining later phases of P and S waves from slab earthquakes at depths of ˜40-50 km around Shikoku, we obtain constraints on the shape of the subducting Philippine Sea plate and the structure around the mantle wedge. Although the mantle wedge structure as well as the location of contact between the island arc and oceanic crusts can control shallow mantle flow, affecting thermal structure around the plate boundary, it is not easy to infer them because the target often lies beneath the ocean with sparse seismic stations. For slab earthquakes at depths of 45-49 km in northwestern Shikoku, we observe two arrivals of P wave at the Hi-net stations in the azimuth range from the north to the east, which are located on the downdip side. The apparent velocities of the initial and later phases are about 8 and 6.7 km/s, approximating P velocities in the mantle and crust, respectively. Dominant S waves propagate by apparent velocity of about 3.8 km/s, which corresponds to a crustal speed. Because the slow phases at the crustal speeds are not observed or observable only at small distances in the northwestern direction, it is unlikely that the earthquakes occurred within the island arc crust. The observations imply that the oceanic crust where the earthquakes occurred is connected with the island arc crust in the northeastern direction, whereas it is not in the northwestern direction. Synthetic waveforms computed by the 3-D Gaussian beam method do not predict slow phases crossing mantle wedge of high velocity. The observations of the slow phases thus suggest that high-velocity mantle does not intrude the region beneath the Takanawa, Ehime, Peninsula. For an earthquake at a depth of 39km in central Shikoku, we also observe later phases in the downdip direction. For earthquakes at depths of 40-45 km in northeastern Shikoku, on the other hand, we do not observe later phases to the downdip direction.

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Seismic attenuation structure beneath the Hokkaido corner: Imaging the arc-arc collision process

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1. Intruduction

In the Hokkaido corner, the Kuril forearc sliver collides with the northeastern Japan arc. Using data from the nationwide Kiban seismic network and temporary seismic network, we determined high resolution three-dimensional seismic velocity structure beneath this area to understand the collision process between the Kuril and NE Japan forearcs [Kita et al., 2010, EPSL; 2011, AGU Fall Meeting], which revealed that an anomalously low-V zone (crust material) descends into the mantle wedge area and reaches a depth of ˜80 km immediately above the subducting Pacific slab. Many earthquakes also occur in this low-V zone down to -80 km depths. In order for deeper understanding of the collision process, we estimated three-dimensional seismic attenuation structure beneath the Hokkaido corner and compared the obtained seismic attenuation images with the seismic velocity images of Kita et al. [2011].

2. Data and method

We applied the methods of Eberhart-Phillips and Chadwick (2002) and Hada et al. (2010, 2010 JPGU meeting) to seismic waveform data from the Kiban network. We simultaneously determined a value of $t*$, corner frequency, and amplitude level for the calculated spectra. Then, seismic attenuation structure (Q value structure) is imaged using $t*$ values. The study region is 41-45N, 140.5-145E, and a depth range of 0-200 km. We obtained 5721 P-wave and 3579 S-wave spectra from 723 events ($M>2.5$) that occurred in the period from October 2006 to April 2011. Horizontal and vertical grid nodes were set with a spacing of 0.10 degree and 10-30 km, respectively.

3. Result

Obtained images show that low-Q zone are located at depths of 0-60 km beneath the western area of the Hidaka mountain range, whereas the eastern area of it (Kuril forearc) has very high-Q values. The low-Q zone almost corresponds to the low-V zone by Kita et al. [2011]. Western portion of the low-Q zone has relatively lower Q values, where inland-type deep seismicity is active. The fault plane of the 1982 M6.7 Urakawa-Oki earthquake is also located on the edge of the lowest Q portion. These results imply that the occurrence of anomalously deep depth earthquakes in this region is related with spatial distribution of hydrous minerals or fluids.

Keywords: Seismic attenuation structure, Arc-arc collision zone, Geofluids, 1982 M6.7 Urakawa-oki earthquake

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Very-low-frequency earthquakes and imbricate thrusts within the accretionary prism in the Nankai subduction zone

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We describe the possible source faults of very-low-frequency (VLF) earthquakes within the accretionary prism in the Nankai subduction zone, Japan. A high-resolution 3D seismic image of a megasplay fault system in the Nankai subduction zone in the region off Kumano was obtained (Moore et al., 2007). Many centroid-moment tensor solutions for VLF earthquakes were calculated from seismic data observed by on-shore broadband seismic networks (Ito and Obara, 2006). In order to understand the generation mechanism of VLF earthquakes, which are considered to reflect slow slip events, it is important to determine the parameters such as fluid pressure and frictional properties of the source faults the corresponding slow slip events. We compare the locations and fault geometry of moment tensors of VLF events to 3D seismic image, and investigate the possible source faults of VLF earthquakes from the imbricate thrusts that are imaged by performing a 3D seismic survey. Many events located within the accretionary prism near or above the decollement and nodal planes of VLF events were consistent with fault geometry of the megasplay or decollement. The decollement above the plate boundary corresponded to regions with high amplitudes and negative polarities in the 3D seismic image, suggesting that VLF events may occur on faults with high fluid pressure. Sakaguchi et al. (2011) had determined the high localized temperatures to be higher than 380^{o}C by vitrinite reflectance geothermometry in the case of the decollement and megasplay faults. They had suggested that frictional heating accompanied by velocity weakening at a high slip velocity occurred along the decollement and megasplay faults during megathrust events. Our observations suggest that frictional heating at the decollement and/or megasplay fault occurs accompanied by velocity weakening even at medium slip velocities.

Keywords: Very-low-frequency earthquake, 3D seismic reflection survey, Megasplay fault, Decollement

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SCG72-P11 Room:Convention Hall Time:May 22 17:15-18:30

Tectonic tremors and its thermal condition in the Hikurangi Subduction Zone, North Island, New Zealand

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Tectonic tremors are widely detected in the subduction zone around the Pacific since its discovery. The oceanic plates, which are subducting beneath such subduction zone, are usually young (~30Myr). The subduction zone with younger oceanic plate is supposed to have a proper condition for tremor generation, such as a shallower slip transition and a active dehydration reaction from oceanic slab, both of which is considered to be important for tremor generation. However, in North Island, New Zealand, where much older oceanic plate (~80Myr) is subducting, tectonic tremor activities were reported by Kim et al., 2011, Fry et al., 2011 and Ide 2012. In North Island, slow slip events (SSEs) are also well known. Tremor activity and SSEs in such cooler subduction seems to be strange. Therefore, in this study, we aim to understand the physical conditions, especially temperature of tremor source areas in North Island. To find out the physical conditions of tremor source areas in cooler subduction zone would be an important clue for clarifying tremor mechanism.

To detect and locate tremors, we use the envelope correlation method of Ide 2010, 2012. The Data is continuous horizontal velocity seismographs from January 2004 to March 2010 downloaded from GeoNet. The 100 Hz sampling original data is 2~8 Hz band-passed and take envelope, then down sampling to 2 Hz in 300 s time windows. In each time window, if more than 40 pairs of cross correlations of envelope between different stations exceed threshold value, we detect seismic signals and try to locate. We also apply same method to 10~20 Hz band-passed data. We rejected detected signals if more than 10 pairs of correlation exceed threshold in 10~20 Hz data as applied in Kim et al., 2011. We also use duration thresholds and simple clustering method to get clearer image of tremor activity. Our analysis detects and locates short belt-like distributed tremor activities. It is just at the transition zone from deeper SSEs to shallower SSEs and at down dip area of deeper SSEs. We also estimated the absolute depth of tremors using S-P time of tremors obtained from cross correlation between vertical and horizontal components of the same station. The estimated depth of tremors suggests its occurrence on the plate interface though the estimation error is not so small due to low signal-to-noise ratio.

McCaffrey et al., 2008 and Fagereng and Ellis, 2009 already estimate the thermal state of Hikurangi Subduction, North Island. However, the estimation error is not clear in these studies. We are interested in the thermal profile along plate interface, especially possible thermal range around the tremor source areas. Therefore, to assess estimation error is important for us. To estimate the temperature profile on the plate interface, we use the subduction thermal model based on Yoshioka and Sanshadokoro, 2002 using finite difference method. In this model, we consider the viscous dissipation, frictional heating and advection. To assess the estimation error of temperature along plate interface, we try some parameter sets, and then the possible temperature range of tremors source areas in North Island is evaluated.

Keywords: tectonic tremor, subduction, New Zealand, thermal structure

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Possible geofluid driven seismic activity near the Moriyoshi-zan volcano in Akita prefecture, northeastern Japan

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1. Introduction

The great 2011 Off the Pacific coast of Tohoku (Tohoku-oki) Earthquake caused triggered seismicity in many areas apart from the source area. In the inland part of Tohoku district, the induced seismicity is quite high in Akita prefecture. Among the three activated clusters in the prefecture, the one to the north of Moriyoshi-zan volcano is quite interesting, because the earthquakes form an unusual vertical column with a height of about 5 km. Considering a possible existence of geofluid beneath the source area inferred from previous studies, the examination of activity of this cluster is important to clarify the relation of induced earthquakes to geofluid.

2. Seismic Activity

The Moriyoshi-zan volcano is a Quaternary volcano located to the west of the Hachimantai volcano along the volcanic front of northeastern Japan. The column-like earthquake cluster was formed from May 2011, about two months after the Tohoku-oki earthquake. The process of column formation is unique. The activity started at the bottom, then elongated vertically forming a central column, and extended horizontally with less seismicity in the central column. This process suggests the migration of geofluid from the bottom followed by horizontal permeation.

3. Reflected Phase

A prominent feature of the seismograms observed at stations around the volcano is a reflected phase that appears on tangential component. This SxS phase is commonly observed for earthquakes in the cluster. Similar phase has previously observed from an earthquake swarm in 1982 [1]. A plane of refection was estimated using the travel time data of SxS phase from the 1982 swarm [1]. The existence of reflector strongly suggests the concentration of geofluid in its location.

4. Discussion

Moriyoshi-zan area is one of the source areas of deep low-frequency microearthquakes occurring mainly beneath active volcanoes in the northeastern Japan [2]. The low-frequency earthquakes that occur well below the elastic plastic boundary are interpreted as the events generated by magmatic activity of mantle diapirs in the uppermost mantle [2]. In the cross-sectional view of seismicity, the westward bottom of reflector is close to the upper limit of low-frequency earthquakes and the eastward top seems to reach the bottom of column-like cluster. From this we can image a pathway of geofluid from the upper mantle to the source of column-like cluster. However, we should note that the horizontal location of reflector and column-like cluster is separated about 5 km. Thus, to conclude if the earthquakes that formed the column-like cluster were driven by geofluid, we need to estimate the present location of reflector using arrival times and waveform characteristics of SxS phase observed in 2011.

Acknowledgments

We used hypocentral parameters of the JMA catalog that was prepared by the JMA and the Ministry of Education, Culture, Sports, Science and Technology in Japan. We thank JMA, NIED, Tohoku University, and Aomori Prefecture for providing waveform data used for our phase picking of hypocenter location.

References

[1] Hori, S, and A. Hasegawa, Zisin (J. Seism.Soc. Jpn.) 44, 39-48 (1991).
[2] Hasegawa, A. and A. Yamamoto, Tectonophysics, 233, 233-252.

Keywords: geofluid, Moriyoshi-zan volcano, induced earthquakes, reflector, low-frequency earthquakes

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Seismicity of deep low-frequency and shallow induced earthquakes near the Moriyoshi-zan volcano in the Akita prefecture

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Deep low-frequency earthquakes occur mainly around active volcanoes in northeastern Japan. These events are thought to be generated by geofluid such as magma or supercritical aqueous fluid, however, there is no direct evidence so far to support the idea. The great 2011 Off the Pacific coast of Tohoku (Tohoku-oki) Earthquake caused triggered seismicity in many areas apart from the source area. The investigation of relation between the induced shallow crustal earthquakes and deep low-frequency earthquakes may be helpful to examine the effect of geofluid. To do this, we plot spatiotemporal distribution of both the shallow ordinary events and deep low-frequency earthquakes for the source areas of low-frequency earthquakes. We found that the activity of low-frequency events in some areas changed after the Tohoku-oki earthquake. For example, the activity has decreased in a shallower source area beneath Iwate volcano. Anomalous induced seismicity was found in an area to the north of Moriyoshi-zan volcano in the Akita prefecture. The earthquakes form an unusual vertical column with a height of about 5 km. In addition, a reflected phase is commonly observed for the events in the column-like cluster. This area is also one of the source areas of deep low-frequency earthquakes. Before the Tohoku earthquake, the low-frequency earthquakes have been occurring intermittently at a depth range of 25-40 km. After the Tohoku-oki earthquake, the range became shallower to 25-30 km, which suggests the migration of geofluid and resultant increase in seismicity started two months after the Tohoku-oki earthquake.

Keywords: deep low-frequency earthquake, geofluid, Moriyoshi-zan volcano

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Frictional rate dependence of thrust materials in accretionary prisms and its implication for VLFEs

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Recent seismological studies identified that very low frequency earthquakes (VLFEs) occurred on thrusts within accretionary prisms or at plate interfaces. On the other hand, clay-rich accreted sediments commonly show velocity-strengthening behavior, which may be unfavorable for occurrence of slow slip events. Here we examined the characteristics and the frictional rate dependence of the thrusts in the Eocene Shimanto accretionary complex of Okinawa Island (Kayo Formation).

The Kayo Formation consists of coherent trench-fill turbidites and it was deformed by folds and thrusts during off-scraping accretion under the subduction of young oceanic crust, possibly representing an on-land analog of the Nankai and Ryukyu subduction zones where VLFEs occur on thrusts within accretionary prisms. Two representative thrusts in the Kayo Formation develop in quartz-rich sandy materials, and the fault zones are composed of cataclastic slip zone, amalgamated slip zone, foliated zone, fibrous quartz veins, and sandstone cemented by quartz, suggesting the fluid saturated conditions during faulting.

To determine the friction rate dependence on the thrust materials, the frictional experiments were conducted on the samples taken from the cataclastic slip zone showing random fabric, the foliated zone, and the host rock (quartz-rich sandstone) at slip rates of 0.0026 - 0.026 - 0.26 - 2.6 mm/s and normal stress of 1.0 MPa under wet conditions using a rotary-shear friction testing apparatus in Kyoto University. At slip rates of 0.0026 - 0.026 - 0.26 mm/s, the cataclastic zone and the host rock show velocity-weakening behavior with frictional rate dependence parameter (a-b) ranging -0.0038˜-0.0013 and -0.0032˜-0.0016, respectively, whereas the foliated zone exhibits velocity-strengthening behavior (a-b=0.0003˜0.0012). At slip rate of 0.26 - 2.6 mm/s, all samples show velocity-strengthening behavior. Microstructural and XRD analyses reveal that velocity-weakening samples show the localized cataclasis along the boundary between gouge and specimen with its quartz and clay minerals contents being 58.9 - 75.8 wt.% and 4.9 - 7.7 wt.%, respectively, while velocity-strengthening sample indicates the clay foliation outside the localized slip zone with lower quartz content (51.5 wt.%) and higher clay content (23.9 wt.%). These features are consistent with occurrence of the fault rocks along the thrusts in the Kayo Formation.

In summary, our field and experimental data suggest that frictional instability tends to generate along quartz-rich material (e.g., quartz-rich sandy materials and quartz veins) but frictional stability increases at higher slip rates of 0.26 - 2.6 mm/s regardless of mineral composition, which will be favorable for VLFEs occurrence in accretionary prisms.

Keywords: very low frequency earthquakes, Kayo Formation, velocity-weakening, quartz-rich sandy materials

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Permeability of shallow nankai subduction zone and its role for mechanical property

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Megasplay faults branching upward from the plate-boundary interface (subduction zone) is thought to be active and contributed to generate recurrent ravaging tsunamis. The rupture and coseismic slip must have propagated to frontal thrust (or shallow portion of decollement) and caused tsunamigenesis as well. Rock physical property and stress state in addition to fault geometry are key parameters that influence on the rupture path of the branching faults in subduction zones. Therefore we measured permeability and frictional properties of core materials retrieved from the megasplay fault zone (site C0004) and the frontal thrust (site C0007) in the shallow part of the Nankai subduction zone in the Nankai Trough during IIODP Expedition 316.

Friction tests were performed by using the rotary shear testing apparatus in Kochi Core Center. The core samples were crushed and then disaggregated to gouges ($<$0.2 mm of grain size) before experiments. 1g of the gouge powder was placed between a pair of solid-cylindrical Indian sandstone specimens (10^{-15} to 10^{-16} m^2 of permeability), 25mm in diameter. Teflon sleeve was used to prevent gouge powders from leaking during rotation of a sandstone cylinder. We rotated one side of Indian sandstone cylinder at a constant speed during friction test at about 1.5 MPa of normal stress. Permeability was measured before and after 7.9 m slip displacement at high (1.05 m/s) and low velocities (0.013 m/s), from which we estimated the shear-induced permeability change in an experimental fault gouge.

After sliding, permeability increased for dry gouge and decreased for wet gouge. The high-velocity friction test under dry condition yielded a larger reduction in permeability than the low-velocity friction test, whereas the opposite trend was observed in wet conditions. These trends are observed in megasplay fault material and the frontal thrust material in common. We attribute the velocity dependence on the permeability change after wet experiment to the effects of thermal/mechanical pore pressurization upon shear-induced compaction, because the pore pressurization by frictional heating has prevented further compaction and permeability reduction in high velocity tests.

The large friction coefficient of the megasplay fault material in the slow and wet friction tests is explained by higher permeability and homogeneous shear deformation that promotes faster shear-induced compaction. On the contrary, the lower friction coefficient and a smaller reduction in permeability due to friction in the frontal thrust sample is due to the slower shear compaction stemming from the formation of localized shear texture and lower gouge permeability. The similarity in post-shear permeability under wet condition in high-velocity friction for the two gouges may account for the similar friction coefficients, assuming that the thermal pressurization process controls high-velocity frictional behavior. Symmetric boudin structure observed after high-velocity friction test may represent evidence of hydrofracturing induced by pore pressurization.

Our results indicate that large stress drop is expected for the megasplay fault during seismic slip, and it may enhance the large slip displacement than in the frontal thrust. Therefore a risk of tsunami genesis could be higher if seismic rupture is propagated to the megasplay fault not to the frontal thrust in Nankai subduction zone.

Keywords: permeability, Subduction earthquake, friction coefficient, NantroSEIZE

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SCG72-P16 Room:Convention Hall Time:May 22 17:15-18:30

Frictional property of gouge materials under high velocity and moderate water pressure condition

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Fluid can act as important roles in faulting and earthquake cycle processes. Geochemical analysis, recently, provided the chemical anomaly in the Chelungpu fault, and this anomaly is explained by the fluid-rock interaction in the fault zone induced by thermal pressurization during co-seismic friction (Ishikawa et al., 2008). However the role of fluid in a fault for a mechanical process and a chemical reaction is still a matter of debate. In addition, we had never achieved high velocity friction experiments to reproduce the water-rock interaction. Here, we designed the rotary shear apparatus that can perform shear deformation of powdered gouge materials with water as pore fluid under high pore pressure condition. We used core samples from the Taiwan Chelungpu fault Drilling Project (TCDP) of Hole B near the fault zones. We used sample holder with 30/60 mm internal/external diameter. We rotated gouge specimen until displacement reaches to 15 - 30 m, and 0.1 to 0.4 of the equivalent slip velocity were applied. We applied normal stress from 5 to 15 MPa and pore pressure from 2 to 5 MPa. We conducted two types of friction test: one is drained condition test that pore pressure is kept at a constant value, and the other is undrained condition test that normal stress is kept constant and that allows pore pressure change during sliding.

In the most of the drained test, shear stress gradually decreased with slip displacement and finally it reached to the stable value after 5 to 15 m displacement. Temperature at slip surface increased with sliding, and it peaked at several m of displacement. Then it kept at a nearly constant temperature till the end of slip. Steady state shear stress is proportional to effective pressure, and friction coefficient showed about 0.2. In the undrained tests, shear stress decreased with slip displacement as well. In addition pore pressure is gradually increased with sliding until the end of sliding. For example, pore pressure is increased from 2 to 9 MPa at 12 MPa of normal stress and 0.2 m/s of slip velocity. Temperature at slip surface increased dramatically as well. The maximum elevated temperature is about 310 degrees celsius for the drained test, and 320 degrees for the undrained test.

Our results indicate that pore pressure increase during sliding that associates with shear stress reduction in undrained condition is due to frictional heating that expanded the volume of water. However, shear stress reduction could be caused by the other mechanical process as well, such as slip localization or fluidization of gouge material.

Keywords: pore pressure, high velocity friction, thermal pressurization, fault gouge

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Influence of Pore-Fluid Pressure on Elastic Wave Velocity and Electrical Conductivity of Water-Saturated Rock

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Pore-fluid pressure in seismogenic zones can play a key role in the occurrence of an earthquake (e.g., Sibson, 2009). Its evaluation via geophysical observation can lead to a good understanding of seismic activities. It is critical to understand how pore-fluid pressure affects seismic velocity and electrical conductivity. We have studied the influence of pore-fluid pressure on elastic wave velocity and electrical conductivity of water-saturated rocks.

Measurements have been made using a 200 MPa hydrostatic pressure vessel, in which confining and pore-fluid pressures can be separately controlled. Pore-fluid (0.1 mol/l KCl aqueous solution) is electrically insulated from the metal work by using a specially designed pore-fluid pressure controlling system. Elastic wave velocity was measured with the pulse transmission technique (PZT transducers, f=2 MHz), and electrical conductivity the four-electrode method (Ag-AgCl electrodes, f=100 mHz - 100 kHz) to minimize the influence of polarization on electrodes.

Berea sandstone (OH, USA) was used for its high porosity (19.1%) and permeability (˜10-13 m2). It is mainly composed of subangular quartz grains. Microstructural examinations show clay minerals (e.g., kaolinite) and carbonates (e.g., calcite) fill many gaps between quartz grains. A small amount of feldspar grains are also present. The grain size is 100-200 micrometers. Cylindrical samples have dimension of 25 mm in diameter and 30 mm in length. Their axes are perpendicular to sedimentation bed. Elastic wave velocity is slightly higher in the direction perpendicular to the axis than in that parallel to the axis.

Confining and pore-fluid pressures work in opposite ways. Increasing confining pressure closes pores, while increasing pore-fluid pressure opens. For a given pore-fluid pressure, both compressional and shear velocities increase with increasing confining pressure, while electrical conductivity decreases. When confining pressure is fixed, velocity decreases with increasing pore-fluid pressure while conductivity increases. The closure and opening of pores can explain observed changes of velocity and conductivity.

Effective confining pressure is defined by the difference between confining and pore-fluid pressures. Velocity increases with increasing effective confining pressure, while conductivity decreases. However, neither velocity nor conductivity is unique function of the effective confining pressure. For a given effective confining pressure, conductivity significantly increases with increasing confining pressure. Velocity also increases with increasing confining pressure, though it is not so significant. Increasing pore-fluid pressure can compress clay minerals to increase pore space. This might explain observed conductivity change.

Keywords: elastic wave velocity, electrical conductivity, water-saturated rock, effective confining pressure, pore