Insights on Structure and Deformation in the Input Section of the Sumatra Seismogenic Zone: Preliminary Results from International Ocean Discovery Program (IODP) Expedition 362

*Mari Hamahashi[1], Abby Kenigsberg[2], Yehua Shan[3], Paola Vannucchi[4], Peter Vrolijk[5], Lisa McNeill[6], Brandon Dugan[7], Katerina Petronotis[8], Jan Backman[9], Sylvain Bourlange[10], Farid Chemale[11], Wenhuang Chen[3], Tobias Colson[12], Marina Frederik[13], Gilles Guerin[14], Timothy Henstock[6], Brian House[15], Andre Huepers[16], Tamara Jeppson[17], Sarah Kachovich[18], Mebae Kuranaga[19], Steffen Kutterolf[20], Kitty Milliken[21], Freya Mitchison[22], Hideki Mukoyoshi[23], Nisha Nair[24], Satoko Owari[25], Kevin Pickering[26], Hugo Pouderoux[27], Insun Song[28], Marta Torres[29], Tao Yang[30], Xixi Zhao[31]

1. Earth Observatory of Singapore, Asian School of the Environment, Nanyang Technological University, 2. Pennsylvania State University, 3. Chinese Academy of Sciences, 4. Royal Holloway University of London, 5. New Mexico Tech, 6. University of Southampton, 7. Colorado School of Mines, 8. Texas A&M University, 9. Stockholm University, 10. Laboratoire GeoRessources, CNRS-Université de Lorraine-CREGU, 11. Universidade do Vale do Rio dos Sinos, 12. University of Western Australia, 13. Agency for the Assessment and Application of Technology (BPPT), 14. Lamont-Doherty Earth Observatory, Columbia University, 15. University of California, San Diego, 16. University of Bremen, 17. University of Wisconsin-Madison, 18. The University of Queensland, 19. Yamaguchi University, 20. GEOMAR, Helmholtz Center for Ocean Research Kiel, 21. Bureau of Economic Geology, 22. Cardiff University, 23. Shimane University, 24. Ministry of Earth Sciences, Government of India, 25. Chiba University, 26. University College London, 27. University de Rennes I, 28. Korea Institute of Geoscience & Mineral (KIGAM), 29. Oregon State University, 30. China Earthquake Administration, 31. University of California, Santa Cruz

The Sunda Trench where the Indo-Australian Plate subducts beneath the Sunda and Burma Plate, is an active seismogenic zone which generated the 2004 Mw 9.2 mega-earthquake and devastating tsunami offshore Northern Sumatra, characterized by a large shallow slip near the trench and an extremely thick (>4 km) incoming section at the deformation front. To investigate the nature and impact of the incoming section on seismogenic processes, the International Ocean Discovery Program (IODP) Expedition 362 drilled into the Indo-Australian Plate ~225 km distance from the trench at 2 primary sites offshore Northern Sumatra during August to October 2016. Here, we report preliminary results from shipboard structural observation on the recovered cores.

The lithostratigraphic sequence of the oceanic plate acquired from Site 1480 consists of Unit I: subsurface calcareous and silty clay (~26.4 m), Unit II: silty clay and sand of the Nicobar Fan sequence (~26.4-1250 m), Unit III: pelagic gray-green to reddish-brown tuffaceous claystone and chalk (~1250-1327 m), Unit IV: basaltic lava flows and volcaniclastic/tuffaceous sandstone (~1327-1350 m), Unit V: chalk and calcareous claystone with magmatic intrusion/extrusion with abundant mineral veins (~1350-1420 m), and Unit VI: basaltic basement cut by veins (1420 m~). Units I and II exhibit little deformation as observed from the continuously near-horizontal bedding dips (<10°), except for several localized horizons of syn-sedimentary normal faults in Unit II and intervals of slumping and folds. The bottom of Unit II (~460 m interval) was particularly undeformed, possibly reflecting the most distal portion of the fan deposit. A distinct concentration of normal faults was observed in Unit III, characterized by primarily two sets of thin anastomosing normal faults which randomly cross-cut each other. Sand injections and lighter-colored diagenetic spots also occur in the sediments, and the normal faults generally cut through the sand injections but generally leave the diagenetic spots uncut. The flattened geometry of the diagenetic spots overprinting the normal faults and the high conjugate angle (>90°) and curvy geometry of the faults may imply that the normal faulting occurred before significant compaction.

Concentrated deformation in the pelagic section may have occurred in an active ridge environment at that time and thermal subsidence followed by rapid sedimentation of the Nicobar Fan, but the actual mechanism is yet to be revealed.
Ongoing post-cruise research will further examine the internal structure, paleo-stress state, and material properties at these horizons of localized deformation in the input section, and ultimately investigate how they would evolve upon entering the subduction zone through comparison with current stress states and active fault systems.

Keywords: International Ocean Discovery Program, Sumatra Seismogenic Zone, Indo-Australian Plate

Measurements of thermal conductivity of a basalt core sample retrieved from subducting oceanic crust in Nankai subduction zone under high temperature

*Weiren Lin[1,2], Osamu Tadai[3], Masataka Kinoshita[4], Jun Kameda[5], Wataru Tanikawa[2], Takehiro Hirose[2], Yohei Hamada[2], Osamu Matsubayashi[6]

1. Graduate School of Engineering, Kyoto University, 2. Kochi Institute for Core Sample research, Japan Agency for Marine-Earth Science and Technology, 3. Marin Works Japan LTD, 4. Earthquake Research Institute, The University of Tokyo, 5. Graduate School of Science, Hokkaido University, 6. Institute for Geo-Resources and Environment, National Institute of Advanced Industrial Science and Technology

Knowledge of rock thermal conductivity is a key to understand thermal structure in active seismogenic zones such as the Nankai Trough subduction zone, SW Japan. To estimate thermal conductivity at the oceanic crust surface in the seismogenic zone, we measured the thermal conductivity of a basalt core sample retrieved from subducting oceanic basement at a depth of ~573 mbsf in input site C0012 of the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) under high temperature (maximum 160˚C). The high temperature condition corresponds to that at the oceanic crust surface in the updip limit of the Nankai seismogenic zone (~7 km below the seafloor). Thus, we set our high temperature condition of the thermal property measurements up to 160˚C at atmospheric pressure for a dry basalt core sample, and up to 100˚C for a wet basalt core sample at the same pressure condition.
As results of the experiments, thermal conductivity of the dry basalt core sample under high temperature and atmospheric pressure gradually increased with increasing ambient temperature. The thermal conductivity of the wet sample also showed an increasing trend, but the value measured at 100˚C might be strongly influenced by the evaporation of pore water, and consequently revealed a sharp increase between 80 and 100˚C. The thermal conductivity of the wet basalt was ~1.62 W/mK at room temperature. Under atmospheric pressure condition we could not measure the thermal conductivity of the wet basalt at 160˚C, but we estimated the value to be ~1.77 W/mK based on both measured thermal conductivity of the dry basalt sample and literature thermal conductivity data of pore water at the same temperature 160˚C. Generally, for other rock types such as sandstone and granite, however, their thermal conductivity decreases with increasing temperature, in contrast to the thermal conductivity of the oceanic basalt increased with increasing ambient temperature.
The thermal conductivity at ~7km also depends on the in situ pressure condition. We will also show our estimation of the thermal conductivity at ~7km in Nankai subduction zone not only for high temperature but also for high pressure effects.

Keywords: thermal conductivity, high temperature, basalt

Heat flow distribution along the Nankai Trough floor: Correlation with the structure of the incoming oceanic crust

*Makoto Yamano[1], Yoshifumi Kawada[2], Mikiya Yamashita[3]

1. Earthq. Res. Inst., Univ. Tokyo, 2. IRIDeS, Tohoku Univ., 3. JAMSTEC

Surface heat flow observed on the floor of the Nankai Trough should reflect the thermal structure of the incoming Philippine Sea plate (Shikoku Basin). Detailed measurements along the trough axis revealed that heat flow on the trough floor in the central part (between 135˚E and 136˚E) is extremely high and variable, much higher than the value corresponding to the seafloor age. On the east of 136˚E, heat flow steeply decreases eastward to the value consistent with the age with no appreciable scatter. In the area west of 134.5˚E, the observed heat flow is more or less normal for the age and shows low scatter. This peculiar heat flow distribution is well correlated with the structure of the Shikoku Basin oceanic crust. The high and variable heat flow area in the central part corresponds to the youngest part of the Shikoku Basin, which was formed by spreading in the NE-SW direction, whereas the neighboring areas with less scattered and lower heat flow were formed by E-W spreading. Other geophysical data, e.g., seismicity, crustal thickness, and basement topography, also show significant variations around the boundaries between the two spreading directions, indicating that the crustal structure changes across the boundaries. The high heat flow in the central part can be attributed to vigorous fluid circulation in a permeable layer (aquifer) in the subducted oceanic crust, which efficiently transports heat upward along the plate interface (Spinelli and Wang, 2008). It is probable that the permeability structure of the oceanic crust changes at the boundaries between the E-W and NE-SW spreading, which yields variations in vigor and/or pattern of fluid circulation, resulting in the observed high to normal heat flow transitions across the boundaries. Another feature of the heat flow distribution in the central part, high variability, appears to arise from the crustal structure as well. The central part is characterized by large basement relief and heat flow values have negative correlation with sediment thickness; heat flow tends to be high on basement highs. Similar correlation cannot be recognized in the areas formed by E-W spreading. It suggests that the high heat flow variability in the central part may also be due to fluid circulation in the permeable layer. These results indicate that the structure of the Shikoku Basin originated from its spreading history has a large influence on physical/chemical conditions along the plate interface (seismogenic zone of large thrust earthquakes and slow erathquakes) through fluid and heat transportation in the oceanic crust.

Keywords: Nankai Trough, Shikoku Basin, heat flow, oceanic crust, fluid circulation, basement topography

Along-trough variation in the seismic structure of the incoming Philippine Sea plate just seaward of the Nankai Trough

*Ayako Nakanishi[1], Mikiya Yamashita[1], Yojiro Yamamoto[1], Gou Fujie[1], Seiichi Miura[1], Shuichi Kodaira[1], Yoshiyuki Kaneda[2], Nobukazu Seama[3]

1. JAMSTEC, 2. Kagawa Univ., 3. Kobe Univ.

Rupture of large-thrust earthquakes along the Nankai Trough is known by always initiating from off the Kii Peninsula. The segmentation boundary between the 1944 Tonankai (Mw=8.1) and the 1946 Nankai (Mw=8.4) earthquake rupture is locate on the Kii channel, off the Kii Peninsula. Activity of the nonvolcanic deep low-frequency tremors and very low-frequency earthquakes observed around the down-dip limit of the coseismic rupture zone of the last Tonankai and Nankai earthquakes is not homogeneous, and the belt-like tremor zone is divided into several segments bounded by gaps [Obara, 2010]. Largest gap is recognized around the Kii channel between the Shikoku Island and Kii Peninsula.
Our recent integrated result of first-arrival tomography based on the 2012 and 2014 wide-angle OBS data shows dramatic along-trough variation in P-wave velocity just beneath the basement of the incoming Philippine Sea plate. Variations in P-wave velocity from ~4km/s to more than 5km/s can be recognized south off the Cape Muroto, Shikoku Island and the Shima Peninsula, about 50-60km and 20km seaward of the deformation front, respectively. Such dramatic velocity change correspond with the structural boundary observed as variation in the configuration of the basement reflection in the time-migrated section, and the boundary of the plate age of about 20-21.5Ma proposed based on magnetic lineation by Okino [2015]. Similar along-trough structural variation in the incoming Philippine Sea plate can be recognized along two seismic profiles across the central Shikoku Basin far south from the trough axis [Nishizawa et al., 2011]. Furukawa et al. [this meeting] also find out the similar structural change around the eastern margin of the northern Shikoku Basin along several seismic profiles across the Izu-Ogasawara arc [Takahashi et al., 2015]. The low P-wave velocity of the oceanic layer 2 formed at backarc region is concerned to be related to high porosities and arc-related mineralogies [e.g. Dunn and Martinez, 2011]. Seismic velocities decrease in the oceanic crust may also indicate high water contents, which may be one of the causes of the low-frequency seismic phenomena around the down-dip limit of the Nankai Trough subduction seismogenic zone. This structural characteristic is thought to continue northwards to the subducting Philippine Sea plate beneath the southwest Japan, and may cause the segmentation of an earthquake rupture, and heterogeneous activity of the nonvolcanic deep low-frequency tremors and very low-frequency earthquakes.
This study is part of 'Research project for compound disaster mitigation on the great, earthquakes and tsunamis around the Nankai Trough region' funded by MEXT, Japan.

Crustal structure of the eastern Nankai Trough from Full Waveform Inversion of the dense Ocean Bottom Seismometers data

*Andrzej Górszczyk[1], Michal Malinowski[1], Stéphane Operto[2]

1. Institute of Geophysics, Polish Academy of Sciences, 2. Géoazur, CNRS, Université Nice Sophia Antipolis

The Nankai Through region is one of the best sites providing an excellent natural laboratory for studying factors controlling segmentation of the earthquake rupture zones in subduction systems. The area has a ~1300 year historical record of damaging earthquakes and is constantly under intense multidisciplinary scientific investigation. For this purpose enormous number of data are acquired in this region. Among them high quality seismic datasets, including multi-channel reflection seismic (MCS) and wide-angle reflection/refraction seismic (WARR) acquired using Ocean Bottom Seismometers (OBS), provide a great potential for seismic imaging.

Crustal-scale velocity models from 2D marine WARR surveys are usually built using ray-based methods. However their ability to resolve complex structures is limited by factors such as: OBS spacing, width of the Fresnel zone or interpreter's ability to distinguish and associate the picked phases with the model interfaces. From the other hand rapid development of the Full Waveform Inversion (FWI) methodology during last decade allows for automation of the crustal velocity model building in the unprecedented resolution, given that the sufficiently dense acquisitions are used. Additionally, potential of FWI stimulates not only development of the imaging algorithms –but also new acquisition technologies including growing pools of OBS instruments available to the academic community making it possible to acquire dense WARR OBS data in 3D.

Here we present multiscale, layer-stripping strategy for the semi-automatic, high resolution, crustal-scale imaging using FWI. We develop practical workflow including: (i) preprocessing focused on the improvement of the data coherency and boosting low frequencies; (ii) thorough and early stage QC starting from the analysis of the traveltime error in the initial model; (iii) final model validation procedures using source estimation, evaluation of the data fit with Dynamic Image Warping, correlation with PSDM image and the interpretation of crustal phases by the ray-tracing. We successfully apply this workflow to the 2D OBS dataset from the eastern Nankai Through acquired by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) involving 100 OBS uniformly deployed along a 100-km long profile recording air-gun shots extended along 140-km long profile with a 100 m spacing.

As a result we obtain velocity model of the complex subduction zone with clearly delineated shallow and deep structures. In particular in the backstop we observe large-scale stacked thrust sheets covered by sediments of forearc basin. These structures spatially extend to the area of accretionary prism forming Kodaiba and Tokai thrusts. Further into seaward direction we can point sequence of smaller thrusts delineating active wedge covered by slope basins and the thick layers of sediments in the trench. We observe local thickening of the oceanic crust corresponding to the subducting oceanic ridges as well as a sharp low-velocity zone (LVZ) atop the oceanic crust, which represent a damage fault zone created by one of these ridges colliding with the backstop. The top of the LVZ corresponds to a splay fault along which the co-seismic slip can occur during the next large earthquake in the area.

We show that with FWI one is able to retrieve a detailed information on the subduction zone structure that can be used as an input for other studies (e.g. geodynamical modeling). High resolution velocity models accompanied by image from MCS data increase interpreter's ability not only in terms of structural interpretation but also help to understand formation processes. Our study presents great potential of the FWI as a semi-automatic method for better imaging of complex crustal targets being beyond the reach of the WARR or towed-streamer surveys. Further tests of FWI with decimated acquisitions reveal that even datasets with 5km OBS-spacing have potential to deliver satisfactory results in terms of imaging overall crustal structure.

Keywords: subduction zone, crustal-scale imaging, full waveform inversion, velocity model building, OBS data, Nankai Trough

Crustal structure beneath the eastern foot of the Japan Trench outer rise by airgun-OBS survey

*Shuhei Otomo[1], Ryosuke Azuma[1], Ryota Hino[1], Gou Fujie[2], Shuichi Kodaira[2]

1. Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku Univ., 2. Japan Agency for Marine-Earth Science and Technology

Several studies on the seismic structure of the oceanic crust reported presence of evident reflectors in the oceanic lower crust or in the uppermost mantle although the seismic structure of the deeper part of the oceanic crust is thought to be relatively homogeneous. The presence of such reflective structure would be related to the processes of formation and/or growth of the oceanic crust. For an example, the reflectors identified at the uppermost mantle of the Pacific Plate off the Kuril Trench was interpreted as Riedel shears which were formed during the plate motion [Kodaira et al., NGEO, 2014]. To study the development process of the Pacific Plate, we investigate the crustal structure of the old Pacific Plate in the northwestern Pacific before it suffers from bending deformation at the trench by analyzing an airgun-ocean bottom seismometer (OBS) survey conducted in the eastern foot of the Japan Trench outer rise.

We used OBS data collected by the wide-angle seismic survey made in 2010. 23 OBSs were deployed along an NS-running survey line (239 km, in total) at a 6 km spacing. Airgun was fired at every 0.2 km. On the record sections obtained at the OBSs located southern part of the line, the first arrivals with an apparent velocity of ~6.5 km/s, possibly waves refracted in the oceanic layer 3, are found to be associated with clear shadow zones, in which amplitudes of arrivals were remarkably weak. The shadow zones of the first arrival are interpreted to be caused by a negative velocity gradient in the deeper part of the oceanic layer 3. The shadow zones are more distinct on the records obtained at southern OBSs than those at northern OBSs, suggesting lateral variation of the structure near the bottom of the layer 3.

A traveltime analysis using a 2-D ray tracing method was made to construct a 2-D P-wave velocity model explaining the characteristics of OBS data, especially the presence of the shadow zones of the first arrivals. By assuming a low velocity zone (LVZ) in the lower oceanic layer 3 with lateral variation of the thickness, the observed appearance of the OBS records can be well explained [Otomo et al., SSJ, 2016]. On the other hand, we applied a series of waveform analyses to obtain a reflection seismic profile by the OBS data, combining a Seismic Interferometry (SI) technique and a NMO stacking. On the reflection profile based on the OBS records data, continuous and evident signals are imaged at ~ 9.0 s in two-way travel time (TWT) [Otomo et al., JpGU, 2016]. The TWT of the event is not consistent with that of the reflections from Moho discontinuity but is similar to that of the reflections from the top of the LVZ, if such reflection signals are actually observed.

We tried to apply the series of SI-NMO analyses to synthetic OBS seismograms calculated based on the velocity model with the LVZ in the layer 3 required to explain the observed shadow zones of the first arrivals, so than we can make sure if the reflected arrivals from the top of the LVZ can be imaged by the identical analysis applied to the field data. On the reflection profiles by processing the synthetic data, clear reflection events are identified at TWTs of ~9.0 s and ~9.7 s. The shallower reflector coincides with the top of LVZ, whereas the deeper one is the Moho reflection. This test reinforces our interpretation that the reflections from the LVZ were imaged on the profiles derived by the field OBS data. Since the reflection events are more evidently observed in the southern part of the survey line than in the northern

part, the velocity contrast at the top of the LVZ would be larger in the south, where the shadow zones of the first arrivals were more distinct. These features may be consistently explained by assuming strong lateral variation in the LVZ located near the bottom of the oceanic layer 3.

Seismic structure beneath the petit-spot area and its implications

*Gou Fujie[1], Shuichi Kodaira[1], Taro Shirai[1], Annke Dannowski[2], Martin Thorwart[2], Ingo Grevemeyer[2], Jason Phipps Morgan[3], Seiichi Miura[1]

1. Japan Agency for Marine-Earth Science and Technology, 2. GEOMAR, 3. Royal Hollowya Univ. of London

The nature of the sedimentary layer on the top of the incoming oceanic plate is one of key controlling factors on the interplate coupling after plate subduction. In the northwestern Pacific margin off NE Japan, the Pacific plate is generally covered with a sedimentary layer consisting of mainly pelagic sediments of a few hundreds meter thick. However, locally thin sediments areas have been found by existing seismic reflection profiles. One of such thin sediments areas is located at the outer rise of the central Japan Trench and the size is roughly 50km square. This area is known as one of petit spot volcano sites; more than 80 petit spot volcanos are expected in this area (Hirano et al., 2006, 2011).

In 2014 and 2015, we conducted OBS-airgun surveys along a 600 km long 2-D seismic survey line crossing the petit spot area. We deployed 88 OBSs at intervals of 6 km and shot a tuned airgun array of R/V Kairei. We applied a traveltime inversion to model P-wave velocity (Vp) structure and found Vp just beneath the shallowest reflector beneath the seafloor is lower in the petit spot area than that in the other areas. To image the detailed seismic structure of the shallow sedimentary layers, we calculated receiver functions using the active-source seismic data. The receiver function analysis is a technique to image P-to-S conversion interface just beneath each OBSs. At most OBSs, only one P-to-S conversion interface is imaged at the expected time of the basement (top of the oceanic crust). But, in the petit spot area, we observed several P-to-S conversion interfaces. Since the deepest interface at the petit spot area is approximately equal to the basement in other areas, we infer that shallower P-to-S conversion interfaces are located within the sedimentary layer and that these interfaces might be related to the intrusion of sills, because we can expect pervasive sill intrusions beneath the petit spot area based on the observation at the outcrop of a petit spot in the central America (Buchs et al., 2013) and on the petit spot model proposed by Hirano et al. (2006).

The seismic coupling between the overlying plate and the subducting plate is probably affected by the nature of the sedimentary layer of the incoming plate, meaning that the subduction of petit spot area might cause the spatial variation in the interplate coupling after subduction. Although each petit spot volcano itself is very small, existing seismic reflection data suggest that the whole petit spot area, roughly 50 km square, is probably characterized by pervasive sill intrusions. Since the size of this petit spot area corresponds to the coseismic rupture area of M7 ~ M8 interplate earthquakes in the subduction zone of the Japan Trench, the subduction of petit spot areas might be one of the causes for a spatial variations in the distribution of interplate earthquakes in this subduction zone.

Keywords: controlled-source seismic survey, Japan Trench, petit spot volcano

Towards electrical resistivity imaging around outer-rise bending normal faults off the Japan trench

*Hiroshi Ichihara[1,2], Takafumi Kasaya[2], Tada-nori Goto[3], Kiyoshi Baba[4], Makoto Yamano[4]

1. Kobe University, 2. Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3. Kyoto University, 4. the University of Tokyo

Hydration in the oceanic crust and uppermost mantle beneath the outer-rise area is thought to be main source of aqueous fluid in the subduction zone (e.g. Ranero et al., 2003). Thus the mapping of hydrating fluid in outer rise areas is essential to understand dynamics, earthquakes and volcanic activities in subduction zones. Imaging of electrical distribution is useful to detect hydration beneath the outer-rise area because electrical resistivity reflects amount, composition and connectivity of fluid, temperature, and serpentinization. Recent developments of control source electro-magnetic (CSEM) investigation methods allow us to obtain high resolution images of resistivity distribution beneath the outer-rise area (Naif et al., 2015). Thus CSEM experiments is being planned in an outer-rise zone in Tohoku-oki area (incoming Pacific plate near the NE Japan arc). In this study, we introduce a present resistivity model based on natural source EM (magnetotelluric) surveys in this area. The model shows that surface conductive layer is thicker beneath the EM station closer to the Japan trench compared to the farther station (40 and 60 km from Japan trench, respectively). Sensitivity tests indicate that the observed data require the variation of thickness of conductive layer. Thus resistivity imaging is effective to investigate hydration in the outer-rise zone in the Tohoku-oki area. Because CSEM investigations can image more detailed resistivity distribution, high resolution mapping of hydration will be realized in this area. Thus we plan CSEM experiments around the Magnetotelluric survey line in mid 2017. The details of CSEM survey plan will be introduced in the presentation.

Effect of pore water on elastic wave velocity of serpentinites and implication for serpentinization at outer-rise region

*Kohei Hatakeyama[1], Ikuo Katayama[1]

1. Hiroshima university Department of earth and planetary systems science

Recent geophysical surveys at outer-rise regions observed the seismic velocity reduction reaching mantle (e.g., Fujie et al., 2013; Shillington et al., 2015). This is interpreted as seawater could penetrate along outer-rise faults that cut through the oceanic crust, thereby reaching the oceanic mantle and promoting serpentinization (Ranero et al., 2003; Lefeldt et al., 2009). The experiment in laboratory indicated that seismic velocity of peridotite decreases with increasing the degree of serpentinization (Christensen, 2004). The observed velocity is compared with the experimental results, and the degree of serpentinization in mantle is estimated. However, the crack in serpentinite is generated with serpentinization involved with volume expansion (Macdonald and Fyfe, 1985), and it would be filled with water. In this study, we examined the effect of pore water on elastic wave velocity of serpentintie having various porosity, and re-evaluated serpentinizaiton at outer-rise region. The samples were collected from Mineoka Belt in Japan, and dredged from deep seafloor at South Mariana Trench and Tonga Trench. They are low-temperature serpentinite composed of lizardite and chrysotile. Based on petrographic analyses, the degree of serpentinization of those sample was 86-100 %. Porosity was measured by the gas expansion method beads on the isothermal gas equations, and porosity of the samples from Mineoka Belt was 0.3-4.4 % and from deep seafloor were 9.6-27.6 %. Intra-vessel deformation and fluid flow apparatus at Hiroshima University were used to measure the elastic wave velocity. Elastic wave velocity was measured from the pulse transmission method. The experiments were performed under dry and wet conditions, which were controlled on 10 MPa of pore pressure. Confining pressure was up to 200 MPa, and temperature was room temperature. Elastic wave velocities increased with increasing confining pressure, and the velocity at 200 MPa under dry conditions were corresponded with the relationship between density and velocity based on Christensen (2004). Under wet conditions, P wave velocity at low and high confining pressure was 8 % and 3 %, respectively, faster than that under dry conditions. This would suggest that bulk modulus of the rock increased because the pore was filled with water. On the other hand, although S wave velocity of low-porosity samples do not observe the effect of the pore water, at high porosity samples, that was 7 % slower than that under dry conditions. This would imply that although the effect on pore water is not sensitive to shear modules, S wave velocity was reduced because of increasing density. The previous studies proposed that seismic velocity reduction at uppermost mantle is corresponded with 20 % serpentiniizaiton. However, if porosity of serpentinite is 10 % and the pore is filled with water, serpentinization is estimated to 15 %, and less than the previous estimates. Therefore, to evaluate the distribution and the ratio of serpentinite in mantle, porosity in the rock must be exactly understood.

Keywords: Serpentinite, Pore fluid, Elastic wave velocity, Outer-rise region

