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

SCG08-01 Room:105 Time:May 23 14:30-14:45

Absence of stagnant slab: implication for volcanism, back-arc opening and trench migration

Masayuki Obayashi[1*], Fenglin Niu[2], Junko Yoshimitsu[1], Hitoshi Kawakatsu[3], Satoru Tanaka[1], Y. John Chen[4], Jieyuan Ning[4], Stephan P Grand[5], Nozomu Takeuchi[3], Koji Miyakawa[3], Koki Idehara[6], Takashi Tonegawa[1], Ryohei Iritani[6]

[1]JAMSTEC, [2]Rice University, [3]ERI, Univ. of Tokyo, [4]Peking University, [5]University of Texas, [6]Univ. of Tokyo

We obtained three-dimensional P-wave velocity model with a focus on the Northeast China. We combined global data with the data of a passive broadband seismic experiment, NorthEast China Extended SeiSmic Array (NECESSArray) deployed since 2009 for two years. The result shows slow anomalies below the Cenozoic volcanoes around the Songliao basin. The slow anomalies can be traced down to 200km depth. On the other hand fast anomalies are observe below the Songliao basin in the uppermost mantle up to a few hundred km depth. In the mantle transition zone, the slab subducted form the Japan Trench meets to the 660-km discontinuity beneath the orogenic at the eastern margin of the basin. No extended flatten slab is observed to the further west beneath the basin in the transition zone while it is observed to the north and south. It looks like a hole of the stagnant slab.The volcanism around the Songliao basin has been active since about 30 Ma. At approximately the same time, the opening of Japan Sea has taken place and the Izu-Bonin Trench started to migrate rapidly eastward with a clockwise rotation as contrasted with the moderate migration of the Japan Trench. We speculate that absence of the stagnant portion of the Japan slab are caused by a slab detachment and the geological events above were related with the detachment.

Keywords: tomography, transition zone, off-arc volcanism, back-arc opening, trench migration

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

SCG08-02 Room:105 Time:May 23 14:45-15:00

Deep mantle upwelling as the source of Changbaishan volcanism

Stephen Grand[1*], Youcai Tang[1], Fenglin Niu[2], Yongshun John Chen[3], Hitoshi Kawakatsu[4], Satoru Tanaka[5], Jieyuan Ning[3], Masayuki Obayashi[5], James Ni[6]

[1]Jackson School of Geosciences, University of Texas, [2]Department of Earth Science, Rice University, [3]Institute of Theoretical and Applied Geophysics, Peking University, [4]Earthquake Research Institute, University of Tokyo, [5]IFREE, Jamstec, [6]Department of Physics, New Mexico State University

Most magmatism on Earth occurs on plate boundaries and is relatively well understood in the context of plate tectonic theory. Significant intraplate magmatism, however, is not easily explained by plate tectonics and is thus more controversial in its cause. Lower mantle plumes may cause some intraplate magmatism, such as Hawaii, but other regions of magmatic activity seem to have a spatial correlation with convergent plate boundaries, although not closely linked with arc volcanism, and thus are unlikely to be due to lower mantle plumes. Volcanism in Northeast China is an example of magmatic activity that may be related to subduction of the Pacific plate beneath Japan but is relatively far from the volcanic arc. Volcanism was widespread in Northeast China through the Cenozoic, but currently the most active magmatism is occurring in the Changbaishan mountain range along the China- North Korea border.

The NorthEast China Extended Array (NECESSArray) deployed from 2009-2011 provided an unprecedented chance to study in detail mantle structure associated with the evolution of intraplate volcanism in Northeast China and its relation to subduction of the Pacific plate. NECESSArray was a large 2D deployment of 127 broadband seismometers with a station spacing of 70-80 km. Using data collected from the array tomographic inversion for mantle P and S velocity variations was performed as well as analysis of receiver functions. High P and S velocities are observed east of 1260 longitude from 500 to 650 km depth along with a depressed 660 km discontinuity. These anomalies likely represent the deep Pacific slab. We also find, however, a localized cylindrical slow anomaly in the transition zone just to the west 1260 longitude but limited in latitude to 420 to 440 with faster velocities to the south and north that may be stagnant slab. A slight upwarping of the 660 km discontinuity is also associated with the slow seismic anomaly. The slow transition zone anomaly is stronger in S velocity anomaly than P and in the S velocity image is continuous from 660 km depth to a strong shallow mantle slow anomaly beneath Changbaishan volcano. We postulate that either a gap between deep slab at 660 km depth or a piece of slab that sank into the lower mantle creates a path way for upward flow of mantle from the lower mantle that is contributing to the volcanism in Changbaishan. The implications of this scenario will be discussed.

Keywords: seismology, intraplate volcanism, mantle tomography

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

SCG08-03 Room:105 Time:May 23 15:00-15:15

Absence of the Stagnant Slab beneath Northeast China Constrained by a Seismic Station in Mongolia

Nozomu Takeuchi[1*], NECESSArray Project Team[2]

[1]Earthquake Research Institute, University of Tokyo, [2]China, USA, and Japan

Most of previous seismic models suggest that the stagnant slabs are widely distributed in the north western Pacific region. However, after dense broadband seismic network, NECESSArray, was deployed in northeast China, such images are now drastically changing. One of the most interesting features is probably the absence of the stagnant slab beneath northeast China suggested by P delay time tomography (e.g., Obayashi et al., 2011, AGU Fall meeting, S24B-06). Formal resolution tests support the detectability, however, because the image was primarily constrained by teleseismic data, the vertical resolutions in the transition zone may not be sufficiently good to definitely conclude the absence. In this study, we test the absence by using independent dataset with higher vertical resolutions.

The station ULN of IRIS GSN is located at about 26-29 degrees from epicenters of aftershocks of 2011 Japan earthquake. The bottoming points of P are in and around the focused region, and the secondary P therefore have good vertical resolution to the transition zone structure there. These data were not utilized in the previous delay time tomography due to difficulties in travel time measurements of secondary phases.

We previously developed the method for measuring travel times of triplicated P and applied it to the P data observed with NECESSArray and F-net (2011, AGU Fall Meeting, S31E-2295). The method is based on waveform fitting approach, and Simulated Annealing (SA) is used in the optimization. In this study, we applied this method to triplicated P observed with ULN and nearby stations of IRIS GSN and CDSN. We analyzed 192 events in 2009-2011, and about two-thirds of them are aftershocks of Japan earthquake.

We combined the dataset obtained in this study with the previous dataset and conducted delay time tomography. To see which data constrain the absence of the stagnant slab, several models are obtained by using different subsets. We found that, if we use the triplicated and teleseismic data of NECESSArray, we can confirm the absence. If we use only the triplicated data of NECESSArray, the image becomes blurred. However, if we use the triplicated data of both NECESSArray and ULN, we can again confirm the absence. The results suggest that the absence is independently constrained by both teleseismic data of NECESSArray and the triplicated data of ULN.

Keywords: tomography, Earth’s internal structure, China

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

SCG08-04 Room:105 Time:May 23 15:15-15:30

Anisotropic structure of the upper mantle beneath the northeastern China from surface wave analysis

Takehi Isse[1*], Hitoshi Kawakatsu[1], Satoru Tanaka[2], Y. John Chen[3], Jieyuan NING[3], Stephen P Grand[4], Fenglin Niu[5], Masayuki Obayashi[2], Koji MIYAKAWA[1], Koki Idehara[6], Takashi Tonegawa[2], Ryohei Iritani[6]

[1]ERI, Univ. of Tokyo, [2]Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology, [3]Peking University, [4]Univ. of Texas, [5]Rice University, [6]The univ. of Tokyo

In 2009-2011, large-scale high-density seismic array (NECESSArray) in northeast China consisted 120 broadband seismographs has been deployed. We use seismograms observed by these and other temporary observations (NECESSArray, Stagnant Slab Project and BBOBS observation) and permanent network observations in and around China (CB, CD, F-net, IC, II, IU, MY, OHP, RM, TM, TW) to investigate the anisotropic and isotropic three-dimensional shear wave velocity structures in the upper mantle by surface wave tomography technique.

We measured phase speeds of the fundamental and first three higher modes of Love and Rayleigh waves for the source-station pairs using a fully non-linear waveform inversion method by Yoshizawa and Kennett (2002). The measured multi-mode phase speeds are inverted to a 2-D shear wave phase speed structures using an inversion technique by Yoshizawa and Kennett (2004), which allows us to incorporate the effects of finite frequency as well as ray path deviation from the great-circle.

We inverted the multi-mode dispersion curves of Love and Rayleigh obtained by phase speed maps to the anisotropic shear wave velocity model. The reference 1-D model is based on PREM except for the crust for which we adopted the CRUST2.0 model.

We obtained a shear wave velocity structures beneath the northeastern China region. The inverted model has a good resolution in the upper 260 km for isotropic structures and in the upper 460 km for anisotropic structures. Obtained isotropic structure model shows that fast anomalies exist in the Songliao basin and slow anomalies exist in the volcanic region at depths shallower than 120km. Obtained radial anisotropic structure shows that Vsh is faster than Vsv in most of studied region at depths shallower than 150 km and that Vsv is faster than Vsh in two region where southeastern and southwestern part of the Songliao basin at depths deeper than 200km. When we assume that the fast axis of olivine is aligned with the flow direction and this is the cause of the seismic anisotropy, obtained anisotropic structure suggests that horizontal flow is existed at depths shallower than 150km and two vertical flows are existed in the deeper part.

Keywords: surface wave, tomography, anisotropy, upper mantle, northeastern China

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

SCG08-05 Room:105 Time:May 23 15:30-15:45

Seismic imaging of the mantle transition zone and lithosphere deformation beneath NE China

Fenglin Niu[1*], Zheng Liu[2], John Y. Chen[2], Steve Grand[3], Hitoshi Kawakatsu[4], Jieyuan Ning[2], Satoru Tanaka[5], Masayuki Obayashi[5], James Ni[6]

[1]State Key Laboratory of Petroleum Resource and Prospecting,China University of Petroleum, [2]Institute of Theoretical and Applied Geophysics, Peking University, Beijing, China, [3]Department of Geological Sciences, University of Texas at Austin, Austin, USA, [4]Earthquake Research Institute, University of Tokyo, Tokyo, Japan, [5]Institute for Frontier Research on Earth and Evolution, JAMESTEC, Japan, [6]Department of Physics, New Mexico State University, Las Cruces, USA

To better understand the intraplate volcanism, the subduction geometry of the Pacific plate, and lithospheric thinning, we installed 127 broadband seismic stations across northeast China between 2009 and 2011. The NECESSArray covers an area 1800 and 600 km in the EW and NS directions, respectively, with a station spacing of 70-80 km. While seismic tomography offers a direct way to map a descending cold slab and a hot mantle upwelling with a high and low seismic velocity, respectively, receiver function data provides an indirect approach to image them when they interact with the 410-km and 660-km seismic discontinuities. The two discontinuities, which define the upper and lower bounds of the mantle transition zone, are believed to be associated with the two phase transitions of olivine that have a positive and negative Clapeyron slope, respectively. Lateral variations in the transition-zone thickness, as well as variations in the depths of the two discontinuities thus can be used to indirectly map out a descending cold slab and an uprising hot plume. We also measured seismic anisotropy in the upper mantle using core shear phases recorded by the array to investigate mantle flow beneath NE China.

We collected a total of 50,000 receiver-function data from 800 teleseismic events, and employed a common-conversion-point stacking (CCP) method to generate a 3D reflectivity volume beneath the study area. To position the P-to-S conversions to the correct depths, we utilized 3D crustal and mantle models as the reference velocity model to make the time-depth conversion. The 3D reflectivity volume was generated in an area between 115-135E and 40-49N, in the depth range of 200 to 1000 km. We found significant topographic relief on both the 410-km and 660-km discontinuities across the study area. In particular, the 660-km discontinuity is depressed by as much as ˜30-40 km in the western end of the deep seismicity. The depression is elongated along the strike of the deep seismicity and is limited within less than 200 km in the E-W subduction direction. To the west of this depression, the 660-km discontinuity rises suddenly by as much as 20 km in a circular area with a radius of 100 km centered at 123.5E and 42.5N. The depression and uplift correspond well with a high and low velocity anomaly, respectively, in the P- and S-wave tomographic velocity maps at the same depth. Our results thus suggest that stagnant subducted slab may not be the extensive feature of deep subduction in this region, and the origin of the Changbaishan volcano located in the border between China and North Korea may not be derived from dehydration of the flat-lying Pacific plate. The low velocity mantle upwelling arising at the tip of the subducting slab may be the eventual source that feeds the enigmatic volcano.

We employed a multi-event signal-to-noise ratio (SNR) weighted method and obtained measurements of splitting parameters at 126 stations. Overall, the observed SKS splitting times are of low amplitude (0.8 s), indicating that the underlying mantle experienced relatively weak deformation in this region. Overall the study region shows a NW-SE fast direction, which is close to the absolute plate motion (N64W, NUVEL-1A model), but is difficult to conciliate with the EW flow expected by the so-called big-mantle-wedge (BMW) model, which hypothesizes a large-scale mantle upwelling in this region as the deep origin of the Cenozoic volcanism. The observed anisotropy also varies consistently from place to place and exhibits an asymmetric pattern across the Songliao basin. At the southeast and east edge of the Songliao basin, the fast axis aligns along the NW-SE direction, whereas the axis rotates slightly to NNW toward northeast beneath the Jiamusi massif and the Sanjiang basin. At the west edge of the basin where the North South Gravity Lineament (NSGL) is located, we found significant scatter in the fast-axis direction.

Keywords: mantle transition zone, deep subduction, intraplate volcanism, lithospheric dripping, receiver function, SKS splitting

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

SCG08-06 Room:105 Time:May 23 15:45-16:00

New mantle tomography of East Asia: Insight into slab subduction and intraplate volcanism

Dapeng Zhao[1*], Wei Wei[2], You Tian[3], Lucy Liu[1], Jiandong Xu[2], Yaolin Shi[4]

[1]Tohoku University, [2]Institute of Geology, China Earthquake Administration, [3]Jilin University, China, [4]University of Chinese Academy of Sciences

Recently we determined a new, high-resolution, P-wave tomography of the crust and mantle down to 1000 km depth under East Asia by inverting 1,401,797 P-wave arrival times from 17,180 local and regional earthquakes recorded by 2247 seismic stations of local and regional seismic networks in East Asia and temporary seismic stations deployed in the Tibetan plateau (Wei et al., 2012). Our new tomography model has improved the previous tomography model of Huang and Zhao (2006) who used 1012 seismic stations in East Asia, whereas the overall pattern of the new model is nearly the same as those of our previous results (Zhao et al., 2004, 2009; Lei and Zhao, 2005; Huang and Zhao, 2006). Our new tomography shows that the subducted Pacific slab is revealed clearly as a high-velocity (high-V) zone and it becomes stagnant in the mantle transition zone (MTZ) beneath Korean Peninsula and eastern China. The Indian lithosphere is characterized by a high-V anomaly and it is subducting nearly horizontally beneath the entire or most parts of western Tibet and with a small dipping angle to the southernmost part of eastern Tibet. The intraplate magmatism in different parts of East Asia has different origins. The active Tengchong volcano in Southwest China is underlain by a prominent low-velocity (low-V) anomaly in the upper mantle and a dipping high-V zone down to MTZ, which may be caused by the deep subduction and dehydration of the Burma microplate plate (or Indian plate). The Hainan volcano is underlain by a plume-like low-V anomaly that extends down to at least 1000 km depth, whereas the plume seems to be caused by the deep subductions of the Burma microplate (or Indian plate) in the west and the Philippine Sea plate in the east. Beneath the active intraplate volcanoes in and around Korean Peninsula and East China (e.g., Changbai, Ulleung, and Jeju), prominent low-V anomalies are revealed in the upper mantle down to 410 km depth, while a significant high-V zone is imaged clearly in MTZ, indicating that these intraplate volcanoes are caused by the hot and wet upwelling flow(s) in the big mantle wedge (BMW) above the stagnant Pacific slab in MTZ. The origin of the Wudalianchi volcanism in NE China seems to be also affected by lithospheric delamination in addition to the BMW processes.

References

Zhao, D., J. Lei, Y. Tang (2004) Origin of the Changbai volcano in northeast China: Evidence from seismic tomography. Chinese Sci. Bull. 49, 1401-1408.

Lei, J., D. Zhao (2005) P-wave tomography and origin of the Changbai intraplate volcano in Northeast Asia. Tectonophysics 397, 281-295.

Huang, J., D. Zhao (2006) High-resolution mantle tomography of China and surrounding regions. J. Geophys. Res. 111, doi:10.1029/2005JB004066.

Zhao, D., Y. Tian, J. Lei, L. Liu, S. Zheng (2009) Seismic image and origin of the Changbai intraplate volcano in East Asia: Role of big mantle wedge above the stagnant Pacific slab. Phys. Earth Planet. Inter. 173, 197-206.

Wei, W., J. Xu, D. Zhao, Y. Shi (2012) East Asia mantle tomography: New insight into plate subduction and intraplate volcanism. J. Asian Earth Sci. 60, 88-103.

Zhao, D., T. Yanada, A. Hasegawa, N. Umino, W. Wei (2012) Imaging the subducting slabs and mantle upwelling under the Japan Islands. Geophys. J. Int. 190, 816-828.

Zhao, D., Y. Yamamoto, T. Yanada (2013) Global mantle heterogeneity and its influence on teleseismic regional tomography. Gondwana Res. 23, 595-616.

Keywords: intraplate volcanism, subduction zone, slab, Pacific plate, hotspot, mantle plume

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

SCG08-07 Room:105 Time:May 23 16:15-16:30

Constraining the origin of the Yellowstone-Snake River Plain volcanic province using seismic imaging

Richard Allen[1*], Robert Porritt[1]

[1]UC Berkeley

Since the inception of the whole-mantle plume hypothesis, the Yellowstone-Snake River Plain (YSRP) volcanic track has been a candidate location for such a plume. Various alternative hypotheses have also been proposed including a propagating rift (e.g. Christiansen et al., 2002) and, more recently, polodial flow in response to slab rollback (e.g. James et al, 2011). We use seismic imaging techniques, in conjunction with other geological and geochemical constraints, in an attempt to distinguish between these various hypotheses. Our 3D seismic velocity model, DNA12, uses data from the Earthscope and ANSS regional networks, and integrates teleseismic body- and surface-waves with ambient noise constraints. The resulting P- and S-velocity models constrain the structure of the crust, lithosphere and mantle to a depth of ˜1000 km. The models have their best resolution beneath the western two thirds of the US. Beneath the YSRP we find the strongest low velocity anomaly found anywhere in the lithosphere. In the 50-250 km depth range the low velocities are elongated in a northeast-southwest direction along the Snake River Plain. Deeper, in the transition zone, the low velocity is more circular in shape and localized to the northwest of the Yellowstone Caldera with higher velocity anomalies surrounding it. In the deepest part of the model, down to 1000km, the low velocity anomaly becomes much broader again. While the propagating rift hypothesis is inconsistent with the tomographic images, the plume and polodial flow hypothesizes are consistent and complementary. A hybrid model consistent with the images has a deep to mid-mantle heat source (˜1000 km or greater depth) feeding a plume conduit that flows in response to surrounding mantle forces. The early phases, before the 17Ma eruption of the Columbia River Basalts (CRB), would include a plume head buoyantly supporting the flattened Farallon slab. Existing weaknesses in the slab would eventually lead to slab fragmentation allowing the plume head to erupt and form the CRB (Obreski et al., 2010). The flow of the plume tail would then be perturbed and forced to dip towards the northwest in the upper mantle (Smith et al., 2009) while the rollback of the shortened Juan de Fuca slab draws the residual material westward creating the Newberry Volcanic track of the High Lava Plains (Long et al., 2012).

Keywords: Yellowstone, upwelling

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

SCG08-08 Room:105 Time:May 23 16:30-16:45

Cenozoic off-arc volcanisms and mantle dynamics in eastern margin of Eurasian continent

Tetsuya Sakuyama[1*], Jun-Ichi Kimura[1]

[1]JAMSTEC, IFREE

The Cenozoic off-arc volcanism in eastern and northeastern China is characterized by eruption of basalts with high alkalinity. They occurred mainly in northeastern China but are distributed sporadically and widely in space and time in whole these areas. In Paleogene, before opening of the Japan Sea, chemical compositions of basaltic volcanism in eastern China are mainly tholeitic, whereas they are still richer in alkaline than Quaternary subduction volcanism in northeastern Japan. Since Japan Sea started opening in Neogene, Chinese basalts have shifted to transitional between tholeitic to alkalic, and ended up with dominance of strongly alkalic basalts in Quaternary. Here, geochemical characteristics and their spatial distribution of late Cenozoic ($<$ 15 Ma) primitive alkaline basalts in eastern and northeastern China as well as the results of geophysical investigations will be reviewed, and the recent models to explain their origin will be discussed.

Although large geochemical variation can be observed even in young ($<$ 15Ma) alkaline basalts, here we propose two important end-members of alkaline basalts in eastern and northeastern China in terms of major and trace elements and isotope compositions. Low-FeO alkaline basalts are depleted in FeO$*$ ($<$ 10 wt%) and TiO_2 ($<$1.5 wt%), enriched in SiO_2 ($>$48 wt%), Al_2O_3 ($>$14 wt%) for MgO ˜ 10 wt%, and enriched in fluid-mobile trace elements, such as Rb, Ba, K, and Pb. They show enriched Sr-Nd isotopic compositions and are enriched in radiogenic Pb. Changbaishan and Wudalianchi volcano erupted the most extreme low-FeO alkaline basalts, whereas low-FeO basalts are widely and sporadically distributed in eastern and northeastern China. Low seismic velocity zone that continues to the mantle transition zone has been observed especially in the upper mantle beneath Changbaishan volcano. The mantle transition zone beneath northeastern China has higher electrical conductivity than those of other tectonic settings. Taken together, these spatial correlations between low-FeO basalt geochemistry and geophysical structure of the upper mantle have been interpreted as an existence of hydrous mantle upwelling strongly affected by fluid released from sediments on a stagnant Pacific slab.

To the contrary, high-FeO alkaline basalts are extremely enriched in FeO$*$ ($>$ 13 wt%) and TiO_2 ($>$2.5 wt%), depleted in SiO_2 ($<$45 wt%), Al_2O_3 ($<$13 wt%) for MgO ˜ 10 wt%, and depleted in fluid-mobile trace elements. Their trace element compositions are similar to those of the ocean island basalts (OIBs) with HIMU isotopic signatures to which dehydrated subducted oceanic crust has been expected to contribute. High-FeO basalts in eastern China, however, show depleted Sr-Nd isotopic compositions and are depleted in radiogenic Pb, which is much less in radiogenic Pb than the HIMU OIBs. The most extreme high-FeO basalts have been observed in Shandong area, and distribution of high-FeO basalts is limited in middle to eastern China at approximately 119^oE between 30 and 40^oN, which is almost parallel to a trench where Pacific Plate is subducting. None of high-pressure melting experiments on peridotite have reproduced melt with the high FeO$*$ and low Al_2O_3, whereas partial melts with such major element compositions can be generated by contribution of carbonated eclogite. These geochemical characteristics suggest that these basalts have received a significant contribution from dehydrated carbonate-bearing oceanic crust in the stagnant slab, without a long time-integrated ingrowth of isotope systems.

The origin of off-arc volcanism in eastern and northeastern China has been attributed to the upper mantle convection independent of the stagnant slab, contribution of sub-continental lithospheric mantle, or influence from the underlying Pacific stagnant slab. Recent integrated and improved geophysical, geochemical, and petrological studies are consistent with the third model.

Keywords: Cenozoic within-plate alkaline basalt, eastern margin of Eurasian Plate, stagnant Pacific slab, subducted sediment, dehydrated oceanic crust

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

SCG08-09 Room:105 Time:May 23 16:45-17:00

New insights into the Philippine Sea evolution: results from the recent Godzilla Megamullion study

Yasuhiko OHARA[1*], SNOW, Jonathan E.[2], MICHIBAYASHI, Katsuyoshi[3], DICK, Henry J.B.[4], HARIGANE, Yumiko[5], TANI, Kenichiro[6], NELSON, Wendy[2], LOOCKE, Matthew[2], SANFILIPPO, Alessio[7], ISHIZUKA, Osamu[5], YAMASHITA, Hiroyuki[8], ISHII, Teruaki[9]

[1]Hydrographic and Oceanographic Department of Japan, [2]University of Houston, [3]Shizuoka University, [4]Woods Hole Oceanographic Institution, [5]Geological Survey of Japan/AIST, [6]JAMSTEC, [7]University of Pavia, [8]Kanagawa Prefectural Museum of Natural History, [9]Fukada Geological Institute

The Godzilla Megamullion is the largest known oceanic core complex, located in the Parece Vela Basin, an extinct backarc basin in the Philippine Sea. The previous studies, primarily based on poorly-constrained magnetics data, argued that the basin was active from 26 to 12 Ma at an intermediate-spreading rate of 8.8-7.0 cm/year full-rate, although the basin shows the characteristics typical for slower-rate spreading ridges. The most remarkable characteristic is found in peridotite petrology; most peridotites in the Parece Vela Basin are much less depleted than those exposed at comparable spreading rates on other mid-ocean ridge systems. The tectono-magmatic characteristics of the Parece Vela Basin were thus thought unusual and paradoxical.

However, the recent studies, based on the high-density samplings on the Godzilla Megamullion (total 42 sampling locations), show the evidences that the basin became slow to ultraslow environment in its terminal phase. Zircon U-Pb dating of gabbroic rocks from the Godzilla Megamullion reveals that the estimated slip rate of the Godzilla Megamullion detachment fault was approximately 2.5 cm/y; significantly slower than the previous estimate. The morphology and geology of the termination area are similar to those observed in ultraslow-spreading ridges; peridotite exposure along the two major parallel ridges bounded by steeply dipping normal faults, showing that mantle uplift occurred symmetrically along the these normal faults. Decreasing degree of partial melting of the peridotites as well as increased amount of plagioclase-bearing peridotites (showing melt stagnation in the shallow lithospheric mantle) are observed towards the termination of the Godzilla Megamullion.

Presence of axial alkaline volcanic chain is known in some backarc basins (e.g., Shikoku Basin, Japan Basin, South China Basin). It is known that these axial volcanoes were active after the cessation of spreading of the basins; hence these activities are called *post-spreading volcanism*. A 4.2 Ma alkaline volcanism is also known in the Parece Vela Basin, within the segment of the Godzilla Megamullion. However, based on the recent observations at the Godzilla Megamullion, we would hypothesize that the terminal phase of a backarc basin evolution will go through an ultraslow-spreading environment, inevitably erupting alkaline basalts. If this is the case, it would not be necessary to assume post-spreading volcanism. Furthermore, a hiatus period is normally assumed between the cessation of a backarc basin and the opening of a succeeding backarc basin. If our hypothesis is true, then there will be an overlap period of the terminal alkaline basalt volcanism and the rifting of a succeeding backarc basin, no hiatus period is necessary. This hypothesis may revolutionize our general understanding of the dynamics of backarc basin asthenospheric structure.

Keywords: Godzilla Megamullion, Philippine Sea, backarc basin, evolution

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

SCG08-10 Room:105 Time:May 23 17:00-17:15

Divergent volcanic expression during subduction initiation: backarc spreading and boninite eruption

Wei Leng[1*], Michael Gurnis[2], Paul Asimow[3]

[1]Lab of Seismology and Physics of Earth Interior, Univ of Science and Technology of China, China, [2]Seismological Laboratory, California Institute of Technology, USA, [3]Division of Geological and Planetary Sciences, California Institute of Technology, USA

Changes of plate motion may have induced subduction initiation (SI), but the tectonic history and volcanic expression of SI is different from one subduction zone to another. Izu-Bonin-Mariana (IBM) SI, accompanied by strong backarc spreading and voluminous eruption of Boninites, contrasts with the Aleutians which shows neither. Using finite element models coupled with parameterized melting, we explore the mechanics and volcanic patterns for SI evolution. With an imposed velocity, we find three evolutionary modes: continuous without backarc spreading, continuous with backarc spreading and a segmented mode. With an increase in the coefficient of friction and a decrease in the rate of plastic weakening, the amount of convergence needed for SI increases from 20 to 220 km, while the mode gradually changes from segmented to continuous without backarc spreading. With an imposed stress, the amount of convergence needed for SI decreases but neither backarc spreading nor strong volcanism results. Our models provide a basis for understanding the divergent geological pathways of SI: First, IBM evolution is consistent with subduction of an old strong plate with an imposed velocity which founders causing intense backarc spreading and volcanic transitions from basalts to boninites. Second, the New Hebrides SI is in the segmented mode due to its weak plate strength. Third, the Puysegur SI is in the continuous without backarc spreading mode with little associated volcanic activities. Finally, the Aleutians SI had neither trench rollback nor backarc spreading because a constant ridge-push force regulated the slab.

Keywords: subduction initiation, divergent mode, backarc spreading, boninite

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

SCG08-11 Room:105 Time:May 23 17:15-17:30

Ascending flows in the Big Mantle Wedge (BMW) beneath northeast Asia induced by retreat and stagnation of subducted slab

Masanori Kameyama[1*]

[1]GRC, Ehime University

We conducted numerical experiments of mantle convection in order to study the mechanism for the generation of ascending flows in the ”Big Mantle Wedge” (BMW), which has been recently proposed by Zhao and coworkers in order to relate the stagnant Pacific slab with the intraplate volcanism in Northeast Asia. In this study, we consider a time-dependent convection of fluid under the extended Boussinesq approximation in a model of a two-dimensional rectangular box of 2000 km height and 6600 km width. We have included both the exothermic olivine to spinel and the endothermic post-spinel phase transitions at around 410 and 660 km depths from the top surface, respectively. The viscosity of mantle material is assumed to be exponentially dependent on temperature and pressure (or depth). We also take into account the effects of the sudden increase in viscosity at the 660 km depth. The plate subduction is modeled by a downward flow of cold and viscous fluid along with a pre-assigned conduit which mimics the path of the descending slab from the top surface to the mantle transition zone (MTZ). In addition, we take into account the effect of trench retreat, by imposing a oceanward migration of the conduit with respect to the deep mantle.

Our calculations demonstrated that the retreating motion of trench is of the primary importance on the slab stagnation: For a sufficiently fast trench retreat, the subducting slab tends to stagnate near the 660 km depth. In addition, the horizontal extent of the stagnant slab, once it forms in the MTZ, increases with time almost in proportion to the trench retreat. This means that the BMW is extended oceanward in response to the retreating motion of trench and slab and, in other words, the toe of stagnant slab is significantly anchored in the mantle. We also found that the oceanward extension of BMW has a strong control on the flows in the region. In particular, there occurs a local but strong circulation near the oceanward end of the BMW just above the stagnant slab. This local circulation is driven by the subducting and retreating motion of slab, and induces an ascending flow which pulls up cold fluids near the stagnant slab. Our findings suggest that ascending flows in the BMW can be mechanically-triggered most easily near the oceanward end (or a hinge) of the stagnant slab, which is in good accordance with the occurrence of several Cenozoic volcanoes in East Asia above the stagnant Pacific slab.

Keywords: stagnant slab, mantle convection, trench retreat, Northeast Asia, volcanism, Big Mantle Wedge

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

SCG08-12 Room:105 Time:May 23 17:30-17:45

Off-arc volcanism in rollback subduction settings

Thorsten Becker[1*], Claudio Faccenna[2]

[1]University of Southern California, Los Angeles CA, USA, [2]Universita di Roma TRE, Rome, Italy

Seismological imaging has shown ubiquitous small-scale convection in the uppermost mantle in regions such as the Mediterranean and the western Pacific, and volcanism may be connected to subduction dynamics outside regular arc formation. We review how the three-dimensional flow around slabs and slab fragmentation can generate focused upwellings, and argue that these may play a significant role in regional tectonics. This process may be reflected in off-arc volcanism, a topographic swell, and slow seismic anomalies associated with partial melt. Using numerical subduction models, we show that upwellings can be generated both ahead of the slab in the back-arc region (˜600 km away from the trench) and around the lateral edges of the slab (˜100 km away from slab edges). Vertical mass transport, and by inference the associated decompression melting, in these regions appears strongly correlated with the interplay between relative trench motion and subduction velocities. The upward flux of material from the depths is expected to be most pronounced during the first phase of slab descent into the upper mantle or during slab fragmentation.

Keywords: subduction, volcanism, mantle convection, plate tectonics, back-arc spreading

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

SCG08-13 Room:105 Time:May 23 17:45-18:00

Subduction zone dynamics controlled by the hot material next to the subducting slab

Satoru Honda[1*], Alik Ismail-Zadeh[2], Manabu Morishige[3], Igor Tsepelev[4]

[1]Earthquake Research Institute, University of Tokyo, [2]Institut fur Angewandte Geowissenschaften, Karlsruhe Institut fur Technologie, [3]IFREE, JAMSTEC, [4]Institute of Mathematics and Mechanics, Russian Academy of Sciences

The origin and past evolution of seismically detected hot material in the sub-slab mantle under the subducting Pacific plate are studied. Forward modeling studies show that its origin is likely to be originated from the hot material next to the cold sinking material typically observed in the internally heated convection. Backward modeling of thermal structure ubder Japanese Islands and their surroundings show the common source of present hot materials in the sub-slab mantle and the mantle wedge. The results also suggest the leakage of hot material from the sub-slab to the back-arc regions, which is also observed in the forward modeling studies. Thus, the thermal abomaly next to the subducting slab plays potentially important role in controlling the dynamics of subduction zone and back-arc mantle such as back-arc spreading, break-off of subducting plate and geochemical mixing.

Keywords: subduction zone, back-arc opening, backward modeling

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

SCG08-P01 Room:Convention Hall Time:May 23 18:15-19:30

Upper mantle rheology of Sea of Japan inferred from postseismic displacements of the Tohoku earthquake

Nikolai Shestakov[1*], Mako Ohzono[2], Hiroaki Takahashi[2], Mikhail Gerasimenko[1], Shigeru Nakao[3]

[1]Institute of Applied Mathematics, Far Eastern Branch, Russian Academy of Sciences, [2]Institute of Seismology and Volcanology, Graduate School of Science, Hokkaido University, [3]Kagoshima University, Department of Earth and Environmental Sciences

The 2011 Great Tohoku earthquake struck the Pacific coast of northern Honshu, Japan almost two years ago. It generated huge co- and postseismic crustal displacements and deformations in the near-field zone. However, the western part of the far-field zone represented by the Korean Peninsula, northeastern China and the south of the Russian Far East were also being affected by coseismic offsets and have still been demonstrating appreciable postseismic movements. It is obvious that the nature of these deformations is connected not only with the earthquake source geometry and processes but also with Sea of Japan and northeast Asia lithosphere and upper mantle structure and rheology. In this study we determine and analyze the far-field postseismic crustal displacements and deformations induced by the 2011 Great Tohoku earthquake using different GPS data sources in the south of the Russian Far East and Kunashir Island (IGS data, continuously and periodically observed regional geodynamic GNSS networks and other GNSS observations applicable for this study). The maximum value of first-year postseismic displacements exceeded 30 mm in the continent, which is about 60% of the appropriate coseismic offset value. In contrast to the continental stations, the postseismic displacement on Kunashir Island located northward from the rupture has already exceeded its coseismic offset (about 10 mm) more than twice. To explain the observed postseismic displacements we adopted the viscoelastic relaxation mechanism and constructed the lithosphere-upper mantle model consisting of elastic lithosphere layer of 50 km thick and two viscoelastic layers of 200 and 265 km thick with Maxwell rheology. We varied the viscosity of the upper viscoelastic layer from 10ˆ17 to 10ˆ19 Pa s to fit the calculated postseismic deformations to their observed values. Our approach gives the astenosphere viscosity of 5-10∗10ˆ17 Pa s which is relatively low with respect to previous estimates. However, the recent study of Kogan et al., 2011 devoted to determination of the mechanism of postseismic deformation triggered by the 2006-2007 great Kuril earthquakes presented a similar viscosity value. The obtained astenosphere viscosity value allows us to adequately explain the far-field postseismic displacements in our GNSS network but fails to explain the first 50 days after the mainshock. Thus, a question about wide variability and time dependency of Japan Sea and northeast Asia upper mantle viscosity should be carefully investigated in the nearest future.

Keywords: lithosphere-upper mantle model, the far-field postseismic crustal displacements, GNSS observations, The 2011 Great Tohoku earthquake, astenosphere viscosity

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

SCG08-P02 Room:Convention Hall Time:May 23 18:15-19:30

Focal Mechanism Solutions of the Tohoku-Oki Earthquake Sequence and Their Geodynamical Implications

Hongyu Yu[1*], Kai Tao[1], Chen Cai[2], Hao Zhang[1], Yanbin Wang[1], Jieyuan Ning[1]

[1]School of Earth and Space Science, Peking University, China, [2]Department of Earth and Planetary Sciences, Washington University in St. Louis, America

The stress state around Japan Sea region and the evolution of Japan Sea are both concerned by Geoscientists. In this paper, we study the stress state around Tohoku-Oki area by analyzing Harvard CMT solutions of the Tohoku-Oki Earthquake Sequence, which may be divided into four groups. The first one includes low-angle thrust events, which are similar with the main shock. They mainly occurred on the interface between the Pacific Plate and the North American Plate, concentrating on deeper depth of the main rupture zone as well as its north/south ends. The second one contains normal-fault earthquakes with principal extensional direction roughly pointing W-E direction. Most of these earthquakes located in the fore-arc uplift region of the Pacific plate. Some others occurred in the fore-arc accretionary wedge. The third one encompasses normal-fault earthquakes too although their principal extensional directions are roughly parallel the Japan Trench. They occurred in the fore-arc accretionary wedge too. The fourth one includes reverse fault earthquakes whose principal compressional directions are roughly parallel the Japan Trench. They took place mostly in the middle of the main rupture zone as well as its south side. We find that the focal mechanisms of the event sequence occurred in the fore-arc accretionary wedge are obviously different from the foreshocks. Tohoku-Oki Earthquake Sequence has released most of accumulated elastic stress. As a result, Pacific Plate and North America Plate has decoupled in the main rupture zone. Moreover, it might lower the E-W compress stress level in Japan Sea and Northeastern China. We conclude that the release of accumulated stress in regions around Japan Sea and Northeastern China could lower the seismic risk and enhance the volcanic activity, especially in Honshu, where may have volcanic eruption in the near future. However, the Pacific Plate and North American Plate near Honshu are not completely decoupled, even though their stress level is low as yet. Whether the stress state of the fore-arc accretionary wedge can be restored to the stress state before the Tohoku-Oki Earthquake Sequence, how long it will take, as well as if Japan Sea might further expand mostly depend on concrete boundary conditions which need further observation.

Keywords: 2011 Tohoku-Oki Earthquake, Back arc basin, Subduction zone, Japan Sea, Focal Mechanism Solution