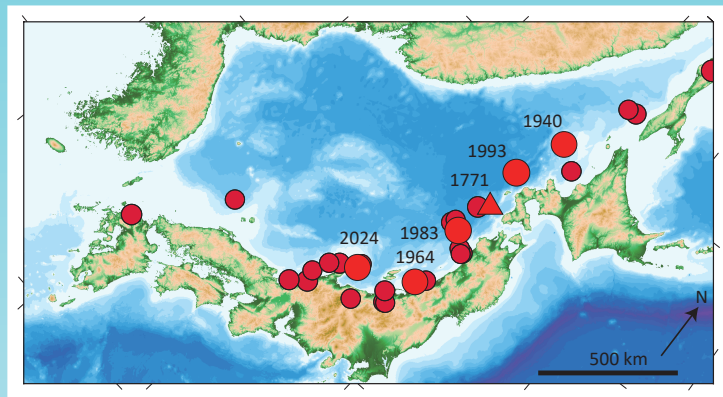


Earth, Planets and Space

Structures, Earthquakes and Tsunami Hazards in the Sea of Japan



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Yours sincerely,

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Editor-in-Chief, *Earth, Planets and Space*

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PREFACE

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Special issue “structures, earthquakes and tsunami hazards in the Sea of Japan”

Masanao Shinohara^{1*}, Tatsuya Ishiyama¹, Aditya Gusman², Tomotaka Iwata³, Kenji Satake^{4,5} and Tatsuhiko Saito⁶

The Sea of Japan covers the back-arc basins of the Japanese island arc and shows intense tectonic activities. The formation of the back-arc basins in the Sea of Japan is believed to be related to the subduction of the Pacific and Philippine Sea plates. Coastal areas of the Japanese islands facing the Sea of Japan are positioned at the edge of the back-arc basins (Sato 1994). In the past, large earthquakes with magnitudes larger than 7 occurred in the coastal areas of the Sea of Japan and caused damages to societies repeatedly by strong ground motions and large tsunamis (e. g. Abe 1975; Satake 1985; Tanioka et al. 1995). On March 11, 2011, large tsunamis and strong ground motions from the 2011 Tohoku-oki earthquake caused devastating damage on the Pacific coasts of the Japanese islands, and it motivated research on seismic and tsunami hazards of the entire Japanese coasts. MLIT (2014) constructed the largest tsunami source fault models in the coastal areas of the Sea of Japan, for calculating tsunami inundation prediction. However, the knowledge and information for distribution and geometries of off-shore active faults, crust–mantle structures, and the history of past tsunamis in the coastal regions of the Sea of

Japan were limited and not sufficient for more accurate estimation of future earthquake and tsunami hazards. The research project named “Integrated Research Project on Seismic and Tsunami Hazards Around the Sea of Japan” (the Japan Sea project) had been carried out by the Ministry of Education, Culture, Sports, Science and Technology, Japan, for eight years since 2013 (MEXT 2021). As a result of the Japan Sea project, the seismic source fault models along the coast of the Japan Sea were constructed (Sato et al. 2021). Under these backgrounds, research on the structures of the crust and upper mantle, seismic activities, tsunamis, and active tectonics in the Sea of Japan and its coastal regions has made significant progress, and seismic and tsunami hazards can be constrained more quantitatively. In addition, research on databases for scientific results and social scientific studies on the hazards view had been performed. In this special issue, 13 papers discuss state-of-the-art methods and results of geophysical and geological observations and modeling, and outcomes of earthquake and tsunami hazards from a background in both earth sciences and social sciences.

Seismic velocity structures provide fundamental information for other geophysical and geological studies. Matsubara et al. (2022) conducted a seismic tomography study for the entire Japanese islands including the Sea of Japan and the Pacific Ocean, using arrival times from reflection surveys and the permanent seismic networks. The shallow structures below the Sea of Japan from the off-Yamagata region to the Noto Peninsula were obtained by using controlled seismic source data. They found that the past large earthquakes in the coastal area of the Sea of Japan occurred at the boundary between high-V_p and low-V_p zones. A deep structure beneath the Sea of

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Japan is indispensable for consideration of tectonics and studies using model simulation. The lithosphere–asthenosphere boundary (LAB) beneath back-arc basins in the Sea of Japan was identified using S-wave receiver functions (RF) (Akuhara et al. 2021). The obtained LAB depths were approximately 45 km beneath the Japan and Yamato Basins and about 70 km beneath the Yamato Rise. The seismic structure estimated using controlled seismic sources has high resolution. Shiraishi et al. (2022) applied reverse time migration (RTM) to offshore wide-angle seismic data acquired with airgun shots and sparsely deployed ocean bottom seismographs (OBSs) for reflection imaging of the Moho discontinuity in the eastern margin of the Sea of Japan. They confirmed that reflections observed in the long offset range were effective in imaging the deep structures. The reflectors could be confirmed to depths of the Moho discontinuity. Their method is effective to identify existing faults for the construction of fault models.

Estimation of shallow seismic structure such as sedimentary layer is also important for seismic hazard estimation. Kagawa and Noguchi (2022) investigated issues of the predominant period of ground motion and derived an underground velocity structure model. They estimated velocity structure from the spectrum ratio of horizontal and vertical components (H/V) of earthquake ground motion to study predominant periods of ground motion in a small plain such as the Tottori plain. It was concluded that the interaction of close predominant periods due to the different layer boundaries may amplify seismic ground motion. In the Hakodate Plain, Hokkaido, small-to-large-sized microtremor array surveys were conducted at five sites to estimate the S-wave velocity structure down to the seismic bedrock for each site (Asano et al. 2022). The new three-dimensional velocity structure model of the Hakodate Plain was developed by integrating the results of microtremor array surveys and other existing geophysical exploration data. The numerical ground motion simulation demonstrated that the amplification and long duration observed in the western part of the Hakodate Plain were reproduced effectively by the new velocity model.

An earthquake with a magnitude of 6.7 occurred off Yamagata prefecture in the Sea of Japan on June 18, 2019. The precise activity of the aftershocks was essential to consider earthquake generation in this area. Shinohara et al. (2022) developed a simple anchored buoy-type OBS for shallow water depths and performed the seafloor aftershock observation for approximately one week. The aftershocks were distributed at a depth range of 2.5 to 10 km and along a plane dipping to the southeast, which was believed to correspond to the fault of the mainshock. Heat flow data are also

essential information to estimate the thickness of the seismogenic layer. New heat flow data were obtained (Matsumoto et al. 2022) from the temperature profiles of the boreholes of the High Sensitivity Seismograph Network (Hi-net). They recognized low heat flow on the forearc side, high heat flow along the Ou Backbone Range, in the Tohoku region, and low heat flow in the alluvial plains on the back-arc side, and confirmed a good correlation between the estimated temperature structure and the lower limit of the seismogenic layer.

Coastal areas along the Sea of Japan, especially in Northeast Japan had repeatedly damaged by tsunamis generated by past large earthquakes. Chiba and Nishimura (2022) conducted geological surveys to investigate tsunami deposits and identified that the deposits were brought by the tsunami generated by the 1983 Nihonkai-Chubu earthquake. In the past half of the twentieth century, it is known that four large earthquakes occurred, and tsunamis were generated by the earthquakes in the Sea of Japan. Murotani et al. (2022) examined the causative faults of these large earthquakes in the Sea of Japan using seismic and tsunami data. They found that the examined faults of the past earthquakes were consistent with the fault models developed by the Japan Sea project, although the data were insufficient to estimate the causative faults for some earthquakes.

Active faults in the coastal and marine areas were recently modeled by the Japan Sea project. Satake et al. (2022) investigated the effects of fault parameter uncertainty on the deterministic assessment of tsunami hazards for the submarine and coastal active faults in the Sea of Japan. The fault slip amount is usually calculated from empirical scaling relations and plays an important role in the scenario-based tsunami assessment. Four methods were adopted to estimate the fault slip amounts and compared the coastal tsunami heights from the slip amounts obtained by two different empirical relations. Consequently, it is critical to select an appropriate scaling relation and approximate the fault slip angles and geometries to reduce the uncertainty of coastal tsunami height estimates.

From a social point of view, tsunami disaster mitigation strategies have not been sufficiently developed for coastal communities along the Sea of Japan. Yamanaka and Shimozono (2022) estimated the tsunami inundation characteristics for three major coastal cities along the Sea of Japan using comprehensive simulations for tsunami propagation and inundation based on earthquake and tsunami source scenarios. As a result, the enhancement of existing infrastructure such as breakwaters and river levees should be the priority measure within tsunami risk-mitigation strategies.

Compilation and visualization of geotechnical databases for information such as geophysical and borehole data are useful for studies of various fields on subsurface structures, which can be displayed using a Geographic Information System (GIS). Nishimura et al. (2022) developed a geotechnical information database for the San'in region in southwestern Japan to display the database on a map in a web browser, which is useful for not only earthquake scientists and engineers but also stakeholders. For prevention and mitigation of disaster by large earthquakes and tsunamis, research from a social scientific viewpoint is also essential. Saito et al. (2022) summarize the findings of an attitude survey focused on people's perceptions of seismic hazard maps, which illustrate the risk of an earthquake in each location throughout Japan. From their survey analyses, the general perception of the necessity of countermeasures grew as seismic intensity in the seismic hazard maps increased. The perception of the need for countermeasures depends on the ages of inhabitants and presentation methods of the risks. They proposed that more detailed analysis should be developed to clarify the perception of the transmission of basic risk information.

All 13 papers in this special issue contribute toward advancing various aspects of mitigating seismic hazards for coastal areas of the Sea of Japan. In addition, research on the prevention and mitigation of disasters of large earthquakes and tsunamis should be accelerated by progress in research projects across various fields including social science.

On January 1, 2024, a large earthquake with a magnitude of 7.6 occurred beneath the Noto Peninsula and caused strong shaking and damages in the source area. The event triggered a destructive tsunami that caused widespread damage both within the source area and along the coast of Toyama and Niigata prefectures. Fujii and Satake (2024) inverted the tsunami waveforms and the GNSS data to estimate the slip amount and seismic moment on each of active faults modeled by the Japan Sea project, and indicated a possibility that some faults had small slip amounts during the mainshock. The source area of the mainshock extended to the marine area. The rapid response seafloor seismic observation showed that the aftershock distribution was consistent with the fault model constructed by the Japan Sea project (Shinohara et al. 2025). These results indicate that construction of fault models for large earthquake generation is useful for research for prevention and mitigation of seismic and tsunami disasters. We must continue to develop research in various fields for the coastal areas facing the Sea of Japan and in marine region close to the coast.

Abbreviations

Hi-net High sensitivity seismograph network

H/V	Ratio of horizontal and vertical components of ground motions
GIS	Geographic information system
LAB	Lithosphere–asthenosphere boundary
MEXT	Ministry of Education, Culture, Sports, Science and Technology, Japan
MLIT	Ministry of Land, Infrastructure, Transport and Tourism, Japan
OBS	Ocean bottom seismometer
RF	Receiver function
RTM	Reverse time migration
Vp	P-wave velocity

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Author contributions

All the authors of this article served as guest editors for this special issue. MS and TI drafted the manuscript. All the authors read and approved the final manuscript.

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Lithosphere–asthenosphere boundary beneath the Sea of Japan from transdimensional inversion of S-receiver functions

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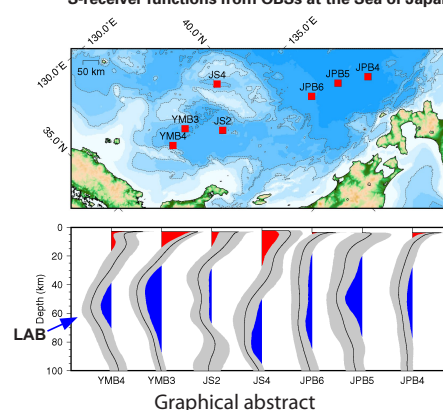


Abstract

The evolution history of the Sea of Japan back-arc basin remains under debate, involving the opening of sub-basins such as the Japan and Yamato Basins. Detailed knowledge of the lithospheric structure will provide the key to understanding tectonic history. This study identifies the lithosphere–asthenosphere boundary (LAB) beneath the Sea of Japan back-arc basin using S-receiver functions (S-RFs). The study area, including the Japan and Yamato Basins, has been instrumented with broadband ocean-bottom seismometers (OBSs). S-RFs from these OBSs show negative Sp phases preceding the direct S arrivals, suggesting the LAB. The S-RFs also show abnormally reduced amplitudes. For further qualitative interpretation of these findings, we conduct transdimensional Bayesian inversion for S-wave velocity models. This less-subjective Bayesian approach clarifies that the low-velocity seafloor sediments and damped deconvolution contribute to the amplitude reduction, illuminating the necessity of such considerations for similar receiver function works. Inverted velocity structures show a sharp velocity decrease at the mantle depths, which we consider the LAB. The obtained LAB depths vary among sites: ~45 km beneath the Japan and Yamato Basins and ~70 km beneath the Yamato Rise, a bathymetric high between the two basins. The thick lithosphere beneath the Yamato Rise most likely reflects its continental origin. However, the thickness is still thin compared to that of eastern Asia, suggesting lithosphere extension by rifting. Notably, the Japan and Yamato Basins show a comparable lithospheric thickness, although the crustal thickness beneath the Yamato Basin is known to be anomalously thick. This consistency in the lithospheric thickness implies that both basins undergo similar back-arc opening processes.

Keywords: Back-arc basin, Lithosphere–asthenosphere boundary, Sea of Japan, S-receiver function, Transdimensional inversion, Ocean-bottom seismometer

S-receiver functions from OBSs at the Sea of Japan



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Precise aftershock distribution of the 2019 Yamagata-oki earthquake using newly developed simple anchored-buoy ocean bottom seismometers and land seismic stations

Masanao Shinohara*, Shin'ichi Sakai, Tomomi Okada, Hiroshi Sato, Yusuke Yamashita, Ryota Hino, Kimihiro Mochizuki and Takeshi Akuhara

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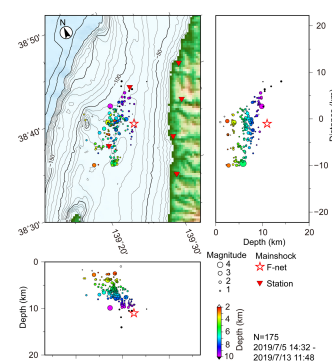
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Abstract

An earthquake with a magnitude of 6.7 occurred in the Japan Sea off Yamagata on June 18, 2019. The mainshock had a source mechanism of reverse-fault type with a compression axis of WNW–ESE direction. Since the source area is positioned in a marine area, seafloor seismic observation is indispensable for obtaining the precise distribution of the aftershocks. The source area has a water depth of less than 100 m, and fishing activity is high. It is difficult to perform aftershock observation using ordinary free-fall pop-up type ocean bottom seismometers (OBSs). We developed a simple anchored-buoy type OBS for shallow water depths and performed the seafloor observation using this. The seafloor seismic unit had three-component seismometers and a hydrophone. Two orthogonal tiltmeters and an azimuth meter monitored the attitude of the package. For seismic observation at shallow water depth, we concluded that an anchored-buoy system would have the advantage of avoiding accidents. Our anchored-buoy OBS was based on a system used in fisheries. We deployed three anchored-buoy OBSs in the source region where the water depth was approximately 80 m on July 5, 2019, and two of the OBSs were recovered on July 13, 2019. Temporary land seismic stations with a three-component seismometer were also installed. The arrival times of P- and S-waves were read from the records of the OBSs and land stations, and we located hypocenters with correction for travel time. A preliminary location was performed using absolute travel time and final hypocenters were obtained using the double-difference method. The aftershocks were distributed at a depth range of 2.5 km to 10 km and along a plane dipping to the southeast. The plane formed by the aftershocks is consistent with the focal mechanism of the mainshock. The activity region of the aftershocks was positioned in the upper part of the upper crust. Focal mechanisms were estimated using the polarity of the first arrivals. Although many aftershocks had a reverse-fault focal mechanism similar to the focal solution of the mainshock, normal-fault type and strike-slip fault type focal mechanisms were also estimated.

Keywords: 2019 Yamagata-oki earthquake, Aftershock observation, Anchored-buoy system, Ocean bottom seismometer, Shallow water seismic observation



Graphical abstract

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Tsunami inundation characteristics along the Japan Sea coastline: effect of dunes, breakwaters, and rivers

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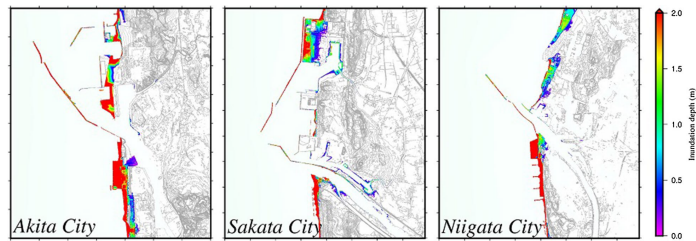
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Abstract

For Japanese coastal communities along the Japan Sea, where the risk of earthquake-induced tsunamis is deemed lower than that along the Pacific Ocean, tsunami disaster mitigation strategies have not been sufficiently developed. This study estimated the tsunami inundation characteristics for three major Japanese coastal cities along the Japan Sea. Based on tsunami simulations for representative coastal areas, we aimed to identify common vulnerabilities, which included those suggested by previous studies and local governments, to develop disaster mitigation strategies. Comprehensive simulations for tsunami propagation and inundation were performed for coastal areas in Akita City, Sakata City, and Niigata City based on earthquake and tsunami source scenarios developed by the Japanese Government for the Japan Sea area. To demonstrate the effectiveness of the estimated inundation characteristics, tsunami inundation was simulated for each coastal area under varying tsunami source conditions (including excessive tsunami magnitude) with a high resolution of the topography and infrastructure. Natural sand dunes, ports with man-made breakwaters, and rivers with levees are typical topographical features found in urbanized and densely populated areas along the Japan Sea coastline. According to the simulated results, the dunes and port breakwaters contribute significantly to decreasing the total amount of tsunami inundation for the areas behind them. However, the presence of the breakwaters also increases the tsunami heights in the areas immediately beyond the ports. Additionally, even the areas protected by the dunes might be exposed to an inundation risk in which the tsunamis invade a river channel, causing it to overflow. These findings were common to the coastal areas, and could be generally applicable to tsunami inundation for all coastal areas along the Japan Sea. Based on these results, the enhancement of existing infrastructure such as breakwaters and river levees should be the priority measure within tsunami risk-mitigation strategies; these, combined with natural resources such as dunes, can effectively mitigate tsunami disasters.

Keywords: Tsunami, Japan Sea, Akita City, Sakata City, Niigata City, Dune, Breakwater, River



Graphical abstract

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Effects of uncertainty in fault parameters on deterministic tsunami hazard assessment: examples for active faults along the eastern margin of the Sea of Japan

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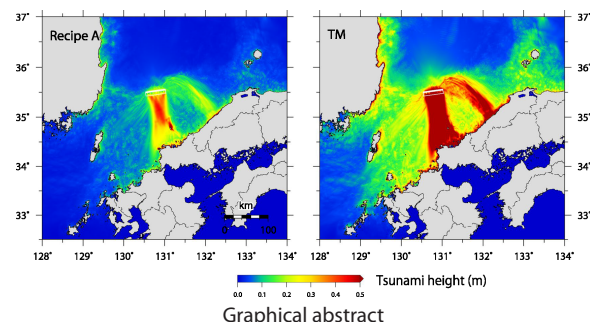
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Abstract

We investigated the effects of fault parameter uncertainty on the deterministic assessment of tsunami hazards for the submarine and coastal active faults in the Sea of Japan that were recently modeled by the Integrated Research Project on Seismic and Tsunami Hazards around the Sea of Japan. A key parameter in scenario-based tsunami assessment is the fault slip amount, which is usually calculated from empirical scaling relations that relate the fault size to the slip. We examined four methods to estimate the fault slip amounts and compared the coastal tsunami heights from the slip amounts obtained by two different empirical relations. The resultant coastal tsunami heights were strongly affected by the choice of scaling relation, particularly the fault aspect ratio (fault length/fault width). The geometric means of the coastal tsunami heights calculated from the two methods ranged from 0.69 to 4.30 with an average of 2.01. We also evaluated the effects of fault slip angles, which are also important parameters for controlling coastal tsunami heights, by changing the slip angles for faults in the southwestern and central parts of the Sea of Japan, where the strike-slip faults are concentrated. The effects of uncertainty of the fault slip angles ($\pm 30^\circ$ from the standard) on the coastal tsunami heights were revealed to be equal to or greater than those resulting from the choice of scaling relations; the geometric means of the coastal tsunami heights from the modified fault slip angles relative to the standard fault slip angles ranged from 0.23 to 5.88. Another important characteristic is that the locations of the maximum coastal tsunami height and the spatial pattern of the coastal tsunami heights can change with varying fault slip angles.

Keywords: Deterministic tsunami hazard assessment (DTHA), Sea of Japan, Scaling relation, Fault parameter uncertainty, Tsunami heights, Integrated research project on seismic and tsunami hazards around the Sea of Japan



Graphical abstract

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Reexamination of tsunami source models for the twentieth century earthquakes off Hokkaido and Tohoku along the eastern margin of the Sea of Japan

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Earth, Planets and Space 2022, **74**:52 DOI: 10.1186/s40623-022-01607-4

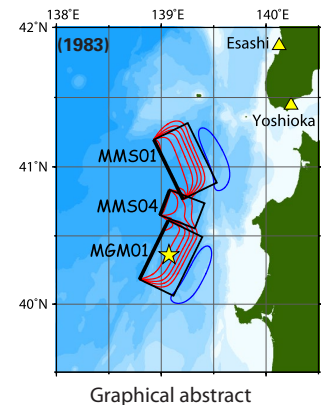
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Abstract

Large earthquakes around Japan occur not only in the Pacific Ocean but also in the Sea of Japan, and cause both damage from the earthquake itself and from the ensuing tsunami to the coastal areas. Recently, offshore active fault surveys were conducted in the Sea of Japan by the Integrated Research Project on Seismic and Tsunami Hazards around the Sea of Japan (JSPJ), and their fault models (length, width, strike, dip, and slip angles) have been obtained. We examined the causative faults of M7 or larger earthquakes in the Sea of Japan during the twentieth century, comprising events of 1940, 1964, 1983, and 1993, using seismic and tsunami data. The 1940 off Shakotan Peninsula earthquake (M_{JMA} 7.5) appears to have been caused by the offshore active faults MS01, MS02, ST01, and ST02 as modeled by the JSPJ. The 1993 off the southwest coast of Hokkaido earthquake (M_{JMA} 7.8) likely occurred on the offshore active faults OK03a, OK03b, and OK05, while the 1983 Central Sea of Japan earthquake (M_{JMA} 7.7) probably related to MMS01, MMS04, and MGM01. For these earthquakes, the observed tsunami waveforms were basically reproduced by tsunami numerical simulation from the offshore active faults with the slip amounts obtained by the scaling relation with three stages between seismic moment and source area for inland earthquakes. However, the observed tsunami runup heights along the coast were not reproduced at certain locations, possibly because of the coarse bathymetry data used for the simulation. The 1983 west off Aomori (M_{JMA} 7.1) and the 1964 off Oga Peninsula (M_{JMA} 6.9) earthquakes showed multiple faults near the source area that could be used to reproduce the observed tsunami waveforms; therefore, we could not identify the causative faults. Further analysis using near-field seismic waveforms is required for their identification of their causative faults and their parameters. The scaling relation for inland earthquakes can be used to obtain the slip amounts for offshore active faults in the Sea of Japan and to estimate the coastal tsunami heights and inundation area which can be useful for disaster prevention and mitigation of future earthquakes and tsunamis.

Keywords: Large earthquakes of the Sea of Japan, 1940 off Shakotan Peninsula earthquake, 1993 off the southwest coast of Hokkaido earthquake, 1983 Central Sea of Japan earthquake, 1983 west off Aomori earthquake, 1964 off Oga Peninsula earthquake, Teleseismic waveform inversion, Tsunami numerical simulation, Scaling relation



Graphical abstract

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Earthquake probability in the National Seismic Hazard Maps for Japan and people's risk perceptions: the search for more effective expression

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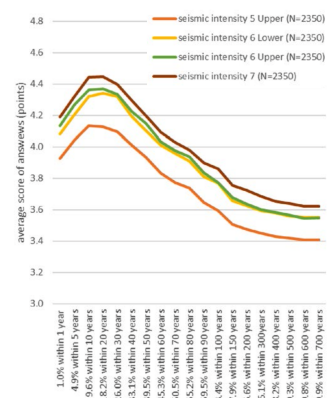
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Abstract

This study summarizes the findings of an attitude survey focused on people's perceptions of seismic hazard maps, which illustrate the risk of an earthquake in each location throughout Japan. These seismic hazard maps depict the likelihood of an earthquake with a seismic intensity of "6 Lower" or more within 30 years, with 3.0% being considered a high possibility. The 3.0% occurrence probability within 30 years can be reworded to 2.0% occurrence probability within 20 years, 0.1% occurrence probability within a year, 4.9% occurrence probability within 50 years, or 39.4% occurrence probability within 500 years when being converted according to a Poisson distribution. In this study, we convert the occurrence probability within 30 years in the seismic hazard maps to obtain that within a year up to that within 1000 years, present the involved risk and demonstrate the yearly probability of the people who see the maps becoming most convinced of the need for countermeasures. Although those are shorter than the occurrence probability within 30 years anyway, it is a characteristic that the peaks existed at the occurrence probability within 10–20 years, not at the occurrence probability within one year or five years. However, the results changed according to the age of the people viewing the maps, and it was when the risk was presented as the occurrence probabilities within 20 and 30 years for the people in their 20–40 s, while it was when the risk was presented the occurrence probabilities within 10 years for the people in their 50–60 s, the perception toward the need of countermeasures increased the most. In addition, regardless of gender and place of residence (coast of the Sea of Japan or the Pacific coast), the perception toward the need of countermeasures peaked at the occurrence probabilities within 10 and 20 years.

Keywords: Earthquake, The National Seismic Hazard Maps for Japan, Risk communication, Probability, Perception of risk, Sea of Japan



Graphical abstract

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Microtremor array surveys and development of the velocity model in the Hakodate Plain, Hokkaido, Japan

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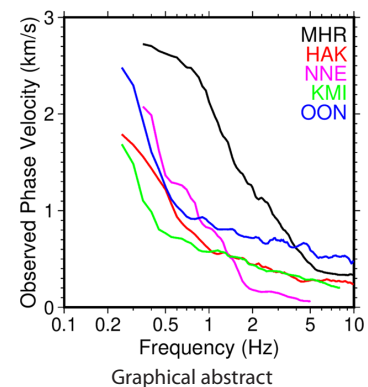
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Abstract

The Hakodate Plain in the southern part of the Oshima Peninsula, Hokkaido, Japan, is a sedimentary basin surrounded by mountains. The vertical displacements caused by active faults along the western margin of the Hakodate Plain increased the basin depth in the western part of the Hakodate Plain. Small-to-large-sized microtremor array surveys were conducted at five sites in the Hakodate Plain to estimate the S-wave velocity structure down to the seismic bedrock for each site to develop a detailed velocity structure model. A new three-dimensional velocity structure model of the Hakodate Plain was developed by integrating the results of microtremor array surveys and other existing geophysical explorations data. This three-dimensional velocity model was modeled as a stack of homogeneous isotropic layers to facilitate its incorporation into the present nation-wide three-dimensional velocity model for ground motion prediction. The bottom depth of the Quaternary sediments is deep along the western margin of the Hakodate Plain. The total thickness of the Quaternary and Neogene sedimentary layers reaches 2.9 km in the western Hakodate Plain. The proposed velocity model was validated by gravity anomaly modeling and ground motion simulation of a moderate-sized inland earthquake. The location of the low-gravity anomaly around the coastline of the Hakodate Bay was improved using the new model. The numerical ground motion simulation using FDM also demonstrated that the amplification and long duration observed in the western part of the Hakodate Plain were reproduced effectively using this velocity model. The spatial variation in long-period ground motion amplifications (period > 1 s) is discussed based on numerical simulations utilizing our three-dimensional velocity model. The highest amplifications at periods of 4 and 5 s were expected in the southwestern Hakodate Plain. The amplification at a period of 3 s was relatively high near the western margin of the plain. Conversely, the spatial characteristics below 2 s were quite complex due to interference of the seismic wavefield inside the basin structure. Variation due to the source location was also relatively high in the shorter period range.

Keywords: Hakodate Plain, Microtremor array survey, Velocity structure model, Ground motion simulation



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Tsunami deposits associated with the 1983 Nihonkai-Chubu earthquake tsunami in coastal forests near Happo Town, Akita Prefecture, Japan

Takashi Chiba* and Yuichi Nishimura

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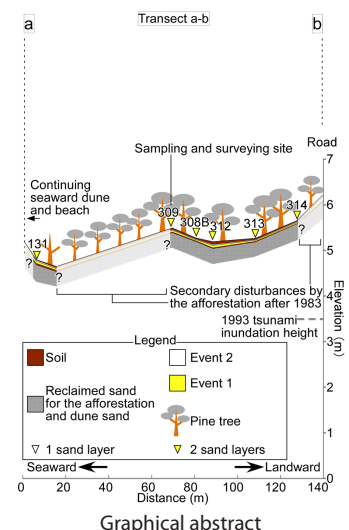
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Abstract

On 26 May 1983 the Nihonkai-Chubu earthquake occurred off the western coast of Noshiro City, Akita Prefecture, Japan. The tsunami associated with this earthquake caused widespread damage to the northeastern coastal region of the Sea of Japan, including Akita Prefecture, and left behind sand and mud deposits. These deposits were first described in the 1990s, but have not been studied further. During December 2019 and January 2020, we conducted geological surveys to investigate post-1948 soil thinning in the pine-based coastal protective forests planted near Happo Town. A sand layer that thinned inland was observed in the soil at depths greater than 10 cm. Because the sand layer contained well-preserved fossil brackish-marine diatoms and exhibited a high bulk density, it is likely that the sand was transported inland from the coast. The sand layer was distributed from the coast to 150–270 m inland, but only within the coastal protective forest. By reference to historical records, we concluded that this sand layer was deposited by the 1983 tsunami, because this region could not have been reached by any event other than the tsunami produced by the Nihonkai-Chubu earthquake. We also observed another sand layer above the tsunami deposits, which may have been formed by Typhoon 9119 on 28 September 1991.

Keywords: 1983 Nihonkai-Chubu earthquake, Tsunami deposit, Typhoon 9119, Aeolian sand, Coastal protective forest, Diatom



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Heat flow data and thermal structure in northeastern Japan

Takumi Matsumoto*, Ryuji Yamada and Satoshi Iizuka

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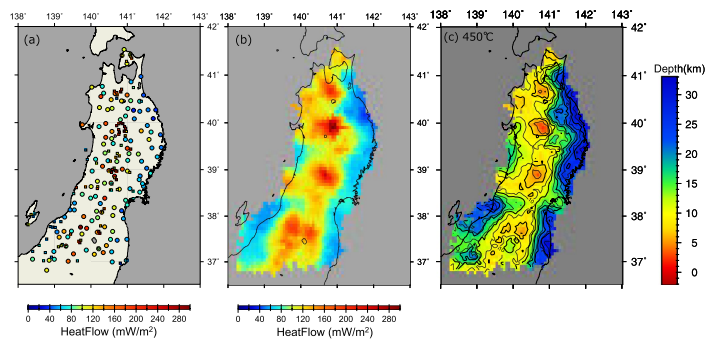
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Abstract

New heat flow data corrected for climate change over Northeastern Japan were obtained using the temperature profile of the borehole of the High Sensitivity Seismograph Network (Hi-net). The obtained spatial distribution of heat flow shows low heat flow on the forearc side, high heat flow along the Ou Backbone Range, and low heat flow in the plains on the back-arc side. However, the distribution is not clearly divided into high and low heat flow along the VF front; for example, the low heat flow extends from near the northern Kitakami Mountains on the forearc side to the Ou Backbone Range crossing the VF, while the high heat flow extends to the central Kitakami Mountains and Sendai plain on the forearc side. In addition, a crustal temperature structure model was developed that considers into account the presence of sedimentary layers, the temperature dependence of thermal conductivity, and differences in heat generation due to lithology. There is a good correlation between this temperature structure and the lower limit of the seismogenic layer, which is between 400 and 450 °C. Compared to previous studies, the crustal thermal structure calculation method assumed is a model whose estimated temperature distribution is sensitive to structural differences; however, a more accurate estimation of the temperature structure is possible if detailed structural information is available. On the other hand, it seems necessary to treat fluid behavior in more detail in areas of high heat flow. However, the estimation of crustal temperature structure, especially in regions with thick sedimentary layers, is considered an improvement over the previous study.

Keywords: Heat flow, Thermal structure, Climate change



Graphical abstract

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Seismic velocity structure along the Sea of Japan with large events derived from seismic tomography for whole Japanese Islands including reflection survey data and NIED MOWLAS Hi-net and S-net data

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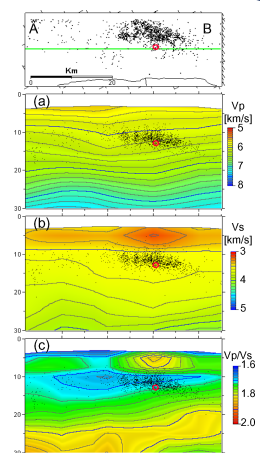
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Abstract

We conducted seismic tomography for entire Japanese Islands including the Sea of Japan and the Pacific Ocean using arrival times from reflection survey as well as the routine seismic network. We successfully imaged the shallow zone along the Sea of Japan from offshore Yamagata to the Noto Peninsula by using air gun data. An extremely low-V shallow zone is imaged between Sado Island and Noto Peninsula. We also obtained detailed seismic velocity structure beneath the Pacific Ocean at depths of 20–50 km using S-net data. The 2007 Noto Peninsula, the 2007 offshore Chuetsu, and the 2019 offshore Yamagata earthquakes occurred at the boundary between high-Vp and low-Vp zones. The west side of the hypocenter of the 2019 offshore Yamagata earthquake at depths of 10–30 km has high-V corresponding to the Mogami Trough. This high-V zone passes through Awa Island and reaches Sado Basin between Sado Island and Honshu. A major rift zone in the Tohoku Arc extending from the Akita region to the Niigata region along the coast of Sea of Japan corresponds to high-V lower crust and a shallow Moho.

Keywords: Seismic tomography, Sea of Japan, Failed rift, NIED S-net, NIED Hi-net



Graphical abstract

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Seismic reflection imaging of deep crustal structures via reverse time migration using offshore wide-angle seismic data on the eastern margin of the Sea of Japan

Kazuya Shiraishi*, Tetsuo No and Gou Fujie

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Abstract

We applied reverse time migration (RTM) to offshore wide-angle seismic data acquired with airgun shots and sparsely deployed ocean bottom seismographs (OBSs) for reflection imaging of the Moho discontinuity in the eastern margin of the Sea of Japan. While seismic tomography is generally applied to wide-angle seismic data for estimating regional velocity, reflection imaging is uncommon due to the low folds from wide-spacing OBS deployment. The long offset reflection data obtained by airgun-OBS surveys are promising for profiling deep crustal structures, which may be able to add constraints on the velocity structures estimated by tomographic inversion. Furthermore, reflection imaging from wide-angle seismic data is useful when only airgun-OBS data are acquired without any MCS data due to weather conditions or restrictions of using streamer cables. In this study, we validated the feasibility of RTM, which is an effective reflection imaging method based on wavefield modelling with the two-way wave equation, using offshore wide-angle seismic data acquired along two crossing survey lines off Niigata–Yamagata. Airgun shot intervals were 200 m in both surveys, and the OBS spacings were 5 km along a 297-km-long line and 8 km or 16 km along a 366-km-long line, except for OBSs near the coast. By applying RTM with velocity models estimated by traveltime tomography of the same OBS data, we successfully imaged clear reflections around depths of 20–30 km. We confirmed that reflections observed in the long offset range were effective in imaging the deep structures that were not imaged by the MCS survey in this region. The depths of reflectors were traced from approximately 20 km in the offshore area to approximately 30 km near the coast, which corresponds to the Moho discontinuity. The depth variation is consistent with the crustal classification that was inferred based on tomography analyses: thick oceanic crust in the Yamato Basin and rifted continental or island arc crust beneath the areas from the Sado Ridge to the coast. Our results from two surveys with different OBS spacings suggested the high potential of the application to a wide variety of wide-angle seismic data for crustal-scale seismic exploration.

Keywords: Wide-angle seismic data, Reflection imaging, Reverse time migration, Deep crustal structure, Moho discontinuity, Sea of Japan

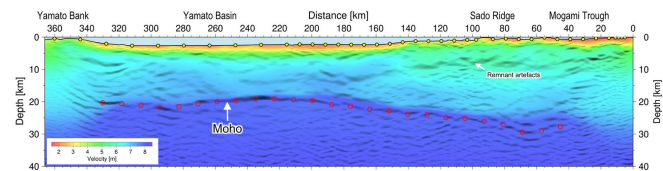


Fig. 4

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Issues related to velocity structure estimation in small coastal sedimentary plains: case of Tottori plain facing the Sea of Japan

Takao Kagawa* and Tatsuya Noguchi

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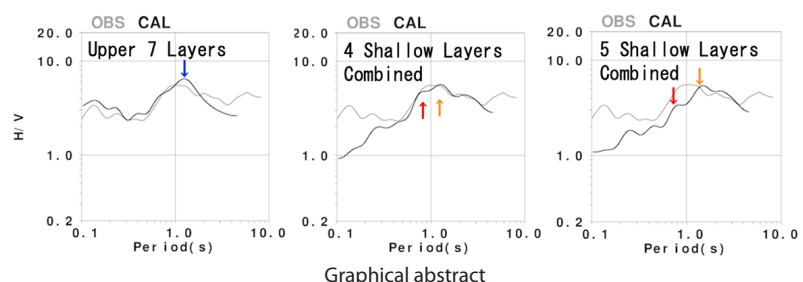
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Abstract

Issues of predominant period of ground motion and derived underground velocity structure model are investigated in the coastal plains affected by the shallow soft sedimentary layer after the last ice age. It is found that two predominant periods due to the shallow soft layer and deeper drastic sedimentary boundaries are close in a small plain such as the Tottori plain, Japan as an example. This study analyzes the underground velocity structure derived from EHVS (H/V spectrum ratio of earthquake ground motions) with the diffuse field theory. It is considered that the interaction of close predominant periods due to the different layer boundaries with high contrast may amplify the seismic ground motion in the period range that affects building structures in small plains in coastal area.

Keywords: Small coastal plain, Predominant period, Velocity structure, Diffuse field theory, Tottori plain



Graphical abstract

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Construction of Web-GIS for integrating geophysical survey data with geotechnical information in the San'in region, southwest Japan

Isamu Nishimura, Tatsuya Noguchi* and Takao Kagawa

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Abstract

Constructing geotechnical information database to collect information such as geophysical survey results and borehole data and then sharing it among researchers and engineers will be useful for developing research on the subsurface structure and the prevention of disasters such as earthquakes and landslides. The geotechnical information includes analysis results based on geophysical surveys, seismic observations, and borehole data. This database can be visually displayed on a map using a Geographic Information System (GIS). The existing analysis results can be checked consecutively. This will allow us to consider new observation plans and to improve the efficiency and accuracy of the subsurface structure model analysis. Therefore, in this study, a database of geotechnical information was developed for the San'in, Japan region. The San'in, Japan region is the western part of Honshu on the Sea of Japan side and includes Tottori and Shimane prefectures. The database of geotechnical information includes the results of microtremor and gravity survey, estimation of the subsurface structure based on seismic records, and borehole data in Tottori and Shimane prefectures. We gather high dense survey points from multiple references in the San'in region, Japan, such that the average space intervals of single station microtremor, microtremor array, gravity survey, and borehole were around 0.1–1, 1–5, 1, and 0.1–1 km, respectively. Furthermore, the corresponding sites of each survey type were conducted over 6000, over 280, over 7500, and over 3700, respectively. In addition, we developed a system to display the database on a map in a web browser (Web-GIS). GIS, Leaflet, a JavaScript library, were used to display the database of geotechnical information using the Geospatial Information Authority of Japan (GSI) tiled map as the base map. The developed database on the GIS system will be a useful tool that can be used by researchers, engineers, and other stakeholders in the future.

Keywords: Database of geotechnical information, Web-GIS, San'in region, Southwest Japan

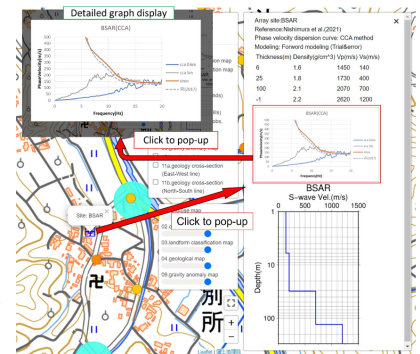


Fig. 5

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