Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

STT056-01 Room:101 Time:May 26 14:15-14:30

New radiography method for small scale structure using soft component of air shower

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Air shower consists of hard component and soft component. Hard component is mainly consists of muon, and soft components is consists of electron, positron and photon. Hard component has strong penetration power, so radiography using hard component has been performed in several volcanoes and seismic faults. However, because of its penetration power, hard component is not suitable for small scale structure thinner than 1 kg/cm2 equivalent to 10m thick water, like buildings, bridges and small hills.

Soft component is suitable for small scale structure, but it requires particle identification. Here, particles identification means distinguishing hard component and soft component. Particle identification can be done very easily by using strong magnet and dense detectors, but it is very hard to use that kind of detector for radiography because of their weight and cost.

There are two kinds of detector for muon radiography, one is comprised of plastic scintillators and the other is comprised of emulsion films. If we can use one of them, we will be able to do radiography thinner structure than 1 kg/cm2 using same detector.

Recently, we found we can measure the lateral distribution of air shower by using current detector for muon radiography comprised of plastic scintillators, and lateral distribution can be used for radiography. Here, lateral distribution means the distance of two particles passed through detector simultaneously. The lateral distribution of soft component is steeper than that of hard component, and the lateral distribution of random component is flat. Also, lateral distribution of hard component will not change after thin structure because hard component has strong penetration power and muons including multi-particle event has much more energy than individual muons. By using these information, distinguishing the soft component, hard component and random component became possible statistically.

To evaluate this newly developed technique, we measured the lateral distribution under the free sky, 0.1m thick concrete, 2m thick concrete and 2.1m thick concrete. We could reproduce the lateral distribution of free sky by simulation completely, and succeeded to reproduce 2m thick concrete and 2.1m thick concrete using their lateral distribution and that under 0.1m thick concrete.

We will report this newly developed radiography method using soft component for small scale structure in detail and the result of measurement. Further improvement and possible application are also discussed.

Keywords: muon, radiography, air shower

Japan Geoscience Union Meeting 2011
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STT056-02 Room:101 Time:May 26 14:30-14:45

Slingram EM surveys for the delineation ofseasonal change in the near-surface resistivity around a river levee

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We conducted resistivity mapping surveys around a river levee for tracking the seasonal change in the near-surface ground water condition. A Slingram-type horizontal-loop electromagnetic induction tool was adopted for the surveys. Slingram method is effective to map large area or profile the near-surface resistivity anomaly. The survey area was set in and around Aino-shima District, Suzaka City, Nagano Prefecture. A total of 6,000 point data were measured over a 1 km by 3 km area around a levee using a commercially available Slingram system GEM2 in rainy and dry seasons in 2009.

The data were processed to reconstruct the near-surface resistivity maps using a 1-D inversion technique proposed by Mitsuhata et al. (2006). It was characteristic that river side of the levee showed relatively high resistivity (low conductivity). In contrast, low resistivity zones were concordantly delineated along the interpreted paleo-channels at the land side. Accordingly, the maps demonstrate that Slingram EM method is helpful to map 2D near-surface resistivity structure that affects ground water flow across a levee system.

Keywords: Slingram EM survey, resistivity, river levee, seasonal change

Japan Geoscience Union Meeting 2011
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STT056-03 Room:101 Time:May 26 14:45-15:00

Development of a magnetic exploration system for seabed resources using AUV and deep-tow system: tests in the Bayonnaise

Keizo Sayanagi[1*], Nobuhiro Isezaki[1], Makoto Harada[1], Takafumi Kasaya[2], Jun Matsuo[3], Tada-nori Goto[4], Kiyokazu Nishimura[1], Takao Sawa[2], Hisatoshi Baba[1], Koki Kawabata[1], Akira Saito[5], Keiko Nakayama[5], Yoshihiro Yamashita[6], Miho Asada[2], Yoshifumi Nogi[7], Nobuhito Onishi[8], Shinobu Omika[2]

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Seabed resources like seafloor hydrothermal deposits have recently attracted much attention. It is, however, difficult to estimate accurate abundance of those resources. Conventional marine (sea-surface) geophysical explorations do not have enough resolution, and an exploratory drilling needs much time and money. Thus, new technology of geophysical exploration near the seafloor is required in order to discover and estimate the resources precisely. From such a standpoint, we have been developing electrical and magnetic exploration systems by using AUV (Autonomous Underwater Vehicle), ROV (Remotely Operated Vehicle), and a deep-tow system in order to estimate structures of the seafloor in detail. Since this study started in 2008, we have made each device of magnetic and electrical exploration systems on an experimental basis. In this presentation, we will report the current situation of the development of the magnetic exploration system, especially about the tests in Bayonnaise knoll area. The magnetic exploration system was tested in the Kumano Basin using AUV "Urashima" and towing vehicle "Yokosuka Deep-Tow" during the R/V Yokosuka cruise in 2009. In this test, we examined the performance of the system through an artificial magnetic target set on the seafloor. In 2010, it was tested more practically in the Bayonnaise knoll area both using a titanium towing frame during the R/V Bosei-maru cruise and using AUV "Urashima" during the R/V Yokosuka cruise. The purpose of these tests was to evaluate the magnetic exploration system in an actual seafloor hydrothermal deposit area for practical applications of that. From these tests, we have succeeded in measuring three components and total intensity of the geomagnetic field using the AUV and total intensity of that using the deep-tow system. The obtained data will contribute to develop the magnetic exploration system for seabed resources, to study magnetic structures of the Hakurei deposit area, the seafloor hydrothermal deposit area, in the Bayonnaise knoll caldera. We will also improve the accuracy of the magnetic measurement, the measurement of three components of the geomagnetic field using the deep-tow system, positioning of the deep-tow system, etc. in order to construct practical magnetic exploration system. Note that this study has been supported by MEXT.

Keywords: seabed resources, sea-floor hydrothermal deposits, geophysical exploration, magnetic, development of instruments

Japan Geoscience Union Meeting 2011
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STT056-04 Room:101 Time:May 26 15:00-15:15

A particle method for modeling seismic ground motion

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A particle-based continuum model for the simulation of seismic wave propagation is presented. Accurate simulation of seismic ground motion for arbitrary topography is a key issue for not only scientific interest but also disaster prediction and mitigation. In the present study, moving particle semi-implicit (MPS) method is applied to seismological simulation. MPS method has some advantages comparing to traditional continuous and discontinuous methods ; first, the introduction of traction-free boundary conditions is easier than finite difference methods (FDM), second, data structure in MPS method is simpler than that in finite element methods (FEM) because we do not need the connectivity between nodes and elements to discretize the analysis object, third, we do not need material parameter calibrations and can use arbitrary material constants unlike distinct element method (DEM) with a hexagonal arrangement. We first introduce moment-tensor earthquake source description to MPS method. Next, we demonstrate that a strong ground motion due to the surface basin structure can be reproduced by MPS method. Finally, we calculate surface wave propagation in the model with arbitrary surface topography. It is found that the method can reproduce the strong ground motion produced by earthquakes with satisfactory accuracy.

Keywords: particle method, seismic wave propagation, numerical simulation

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STT056-05 Room:101 Time:May 26 15:15-15:30

The Investigation of the Active Fault in the Beijing, China, Using Microtremor Survey Method

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The Investigation of the Active Fault in the Beijing, China, Using Microtremor Survey Method

Keywords: the microtremor survey method, array observation, apparent S velocity, active fault

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

STT056-06 Room:101 Time:May 26 15:30-15:45

Determination of S-Wave structure beneath Istanbul, by using Love wave and by Joint Inversion of Rayleigh Wave and H/V

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On August 17, 1999, a devastating earthquake with a moment magnitude of Mw=7.4 struck the Kocaeli and Sakarya (Adapazari) provinces, and part of suburbs of Istanbul in the northwestern of Turkey, a very densely populated region in the industrial heartland of Turkey. This earthquake is considered to be the largest event to have devastated a modern, industrialized area since the 1923 Great Kanto earthquake. This earthquake caused about 30.000 losses of life and collapsed thousands of buildings. Thus, total loss figure amounted to about US$ 16 Billion. Following the losses during this large earthquake, there has been a broad recognition among Turkey governmental, non-governmental and academic organizations of the need for extensive response planning based on detailed risk analysis of likely seismic hazard, microzonation studies and ground-motion researches in Turkey, in general and, Istanbul particular. In this frame, we have been performing a project on the determination of S-wave velocity structure beneath the European side of Istanbul, Turkey. One of the aims of the project is to improve the knowledge about the influence of local geology in the city on the expected earthquake ground motion. In this project , we conducted both array measurements and single station microtremor measurements at 30 sites. We applied SPAC method for the inversion, and used both Love and Rayleigh waves, and H/V technique, as well, to determine the S-wave velocity structure. Furthermore, we compared S-wave velocity-depth model obtained from the inversion of Love wave dispersion curve with that obtained by joint inversion of Rayleigh wave dispersion curve and H/V curve. As a conclusion, we have found that Love waves are more sensitive to shallower parts than Rayleigh waves, since penetration depth of Love waves are shallower than Rayleigh waves. Contrarily, deeper parts are modelled more presizely by the joint inversion of Rayleigh waves and H/V curves.

Keywords: Microtremor, SPAC, Love waves, Rayleigh wave, H/V technique, Istanbul

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STT056-07 Room:101 Time:May 26 15:45-16:00

Quantitative Evaluation of Rock Mass Classification by Using Sonic Logging Data

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Japanese Only

Keywords: Rock Mass Classification, Rock Mass Properties, Sonic Logging

Japan Geoscience Union Meeting 2011
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STT056-08 Room:101 Time:May 26 16:00-16:15

Fast calculation of formation factors of 3-D pore-scale images of geo-materials by renormalization

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The formation factor, the dimensionless electric resistivity of porous rock/sediment saturated with conductive fluid, is an important quantity in geophysical exploration for petroleum reservoirs and groundwater aquifers. In the rock physics related to such exploration, there is a need to calculate formation factors from large three-dimensional (3-D) images of porous rocks/sediments obtained by X-ray microtomography. In the present study, we applied a renormalization technique to quickly estimate the formation factors for various pore-scale image sets of real geo-materials (sandstones, pumice, lava, and sandy sediments). In this method, the effective formation factor is first calculated using Ohm's law and Kirchhoff's law for small subsystems of 2x2x2 = 8 voxels, and this is then upscaled based on the arrangement of voxels in the 3-D image. This method is several orders of magnitude faster than the conventional method because the time-consuming iterative algorithm for solving the 3-D large-scale Laplace equation is not employed. Application of this technique to microtomographic images of real porous rocks/sediments revealed that its accuracy increases with increasing porosity and pore elongation along the direction of the applied electric field and with decreasing pore/grain size. Most importantly, a high degree of elongation of the pore structure along the applied field ensures good accuracy even if the porosity is low and the pore/grain size is large. Taking these effects into consideration, the method can be used to produce a rough but quick estimate of the formation factors for large pore-scale images of geo-materials. Because steady-state thermal and material diffusion obeys the same Laplace equation, the renormalization technique presented here can also be applied to estimate thermal/material diffusivity for natural geo-materials and industrial composite materials, particularly for those having strong prolate structural anisotropy parallel to the applied field gradient.

Ref: Nakashima, Y. and Nakano, T. (2011) J. Appl. Geophys. (in review)

Keywords: resistivity, large-scale simulation, super computing, Laplace equation, X-ray microtomography, Diffusion coefficient

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STT056-P01 Room:Convention Hall Time:May 26 16:15-18:45

Numerical method of tsunami simulation including the effects of seafloor topography

Tomoya Ohata[1*], Hitoshi Mikada[1], Tada-nori Goto[1], Junichi Takekawa[1]

[1]Kyoto Univ.

Japan is surrounded by the sea and has been suffered from tsunami so often. For tsunami disaster mitigation, we should predict the arrival time and the run-up height, and we usually use numerical simulation of tsunami propagation to understand those kinds of information. Many simulations focus on the prediction of the first arrival times and the initial height of tsunami. When tsunami propagates, however, reflected waves are generated by the real change of water depth and influence the tsunami height estimation. In particular, the later phases of tsunami are strongly affected by it, and the prediction about them is difficult by conventional numerical codes. In the case of the tsunami cased by the earthquake at Kuril Islands in 2006, maximum height waves arrived at the lands a few hours after the first arrival of tsunami reached, because the tsunami waves are scattered by the Emperor Seamount Chain. To consider these phenomena, it is necessary to think of the effects of the seafloor topography on propagation of tsunami.

In this study, by introducing the seafloor topography to tsunami simulation, we express the reflected waves and think about the effects of the topography on tsunami propagation. We generate a model that allows us to calculate tsunami propagation considering seafloor topographic variation, such as a slope, on the basis of the 500m-mesh bathymetry data from JODC(Japan Oceanographic Data Center). The simulation is performed using 3 dimensional in-equally spaced grids in FDM(Finite Difference Method). By using this code, we simulate tsunami propagation over the real changes of the water depth of the sea near Japan.

We find that the simulated tsunami shows some features caused by the topography and the propagation is different from that expressed by the conventional method. We conclude that the real seafloor topography is needed to consider for practical tsunami simulation including later phases. Our results indicate that reflection, scattering, need to be accommodated in the propagation of tsunami. So the results will lead to simulate the later phases of tsunami, which is our purpose of this study. On the other hand, studying about the accuracy of the calculation is important to think about the later phases of tsunami. When the grid intervals are sparse, waves with large wave numbers cannot be calculated, and this limitation strongly affects the later phases of tsunami. We consider how the reduction of accuracy affects the expression of tsunami in this study.

Keywords: Tsunami, seafloor topography, simulation method, in-equally spaced grids, later phases of tsunami, accuracy of the calculation

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STT056-P02 Room:Convention Hall Time:May 26 16:15-18:45

Seafloor deformation due to earthquakes with solid-fluid coupling

Nobuaki Tanaka[1*], Hitoshi Mikada[1], Tada-nori Goto[1], Junichi Takekawa[1]

[1]Kyoto University

There are many researches about the generation and propagation of tsunami based on numerical simulation. These researches, however, simulate tsunamis based on a linear long wave theory under the assumption that initial wave shape equals to the static deformation of the seafloor. The deformation of the seafloor is a function of time and space reflecting the dislocation of sub-seafloor earthquakes, and we have to consider the kinetic deformation of the seafloor for more precise simulations. In the past, Suzuki (2006) studied tunami propagation including the kinetic deformation of the seafloor caused by the dislocation of a fault, and considered the influence of solid upon liquid. His research, however, did not perfectly take the interaction between solid and liquid into account, because the deformation of solid and the analysis of liquid could not be coupled at the same time due to numerical difficulties in the simulation. We simulated the propagation of seismic wave to aim at the investigation of the displacement of seafloor considering the coupling between solid and fluid using a finite difference method.

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STT056-P03 Room:Convention Hall Time:May 26 16:15-18:45

Development of controlled-source EM survey using AUV and ROV

Tada-nori Goto[1*], Naoto Imamura[1], Hitoshi Mikada[1], Junichi Takekawa[1], Keizo Sayanagi[2], Makoto Harada[2], Takafumi Kasaya[3], Noriko Tada[3], Takao Sawa[3], Shigeo Matsuda[4]

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The recent growth of world-wide requirement of metals demands advanced explorations for finding metal mine and deposits. Here we propose a new way for exploration of buried submarine massive sulphides with marine controlled-source electromagnetic technique, and magnetic survey. The result of latter suvey is introduced by Sanayagi et al. in this session. We demonstrated feasibility studies using various marine electromagnetic soundings: magnetometric resistivity (MMR) survey, CSEM survey and marine DC resistivity survey. As a result, we confirmed that the electromagnetic responses of each marine electromagnetic survey are very sensitive to the conductive layer simulating the submarine massive sulphide deposits, which is buried at the depth of several tens meters. For example, we demonstrated a CSEM survey with AUV-based source and OBEMs (ocean bottom electromagnetometers). A numerical simulation code for 2.5 dimensional electromagnetic field in the frequency domain is developed. The results shows high attenuation of received signal strength by OBEMs even with far source-receiver offset, when the source-AUV is arranged near the conductive seafloor. It implies a possibility of detection of horizontal extent of deep-sea mine. More quantitative modelling will allow the detailed sub-seafloor structure of deep-sea mine. On the basis of these numerical results, we newly developed our own controlled-source EM survey system for AUV and ROV. One of the instruments, the ROV-based marine DC resistivity survey system, was tested at a real deep-sea mine. The obtained data shows relatively conductive feature compared to the surrounding area. We confirmed a efficiency of our new CSEM survey system with ROV and AUV on imaging the distribution of exposed and buried deep-sea mine.

Keywords: deep-sea mine, controlled-source, EM survey, ROV, AUV

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STT056-P04 Room:Convention Hall Time:May 26 16:15-18:45

Evaluation of developed precise magnetic exploration tools with using the AUV Urashima and deep-tow systems

Makoto Harada[1*], Keizo Sayanagi[1], Nobuhiro Isezaki[1], Takafumi Kasaya[2], Jun Matsuo[3], Takao Sawa[2], Hisatoshi Baba[4], Nobuhito Onishi[5]

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We have developed new precise exploration tools for the seafloor hydrothermal deposits by magnetic method in order to estimate abundance of metallic resources (e.g. Sayanagi et al., 2009). Developed tools are assumed to be used with the underwater platforms such as deep-tow (DT) and autonomous underwater vehicle (AUV).

Since 2009, we have carried out several technical tests and performances by using the helicopter and research vessels. In this session, we introduce the results of the performance tests of following three research cruises.

1) Yokosuka YK09-09 Cruise (19-29 July, 2009; Kumano-Basin)

We carried out AUV Urashima and YKDT (Yokosuka Deep-Tow) dives in Kumano-nada (depth at 2,050m). To inspect the efficiency of equipments, we used a magnetic target which is consisted of 50 neodymium magnets. Four flux-gate (FG) and one Overhauser (OH) magnetometers were set up in the AUV and two FG and one OH magnetometers were used in the DT surveys (Harada et al., 2010a, 2010b). We could obtain the thee-component magnetic field and gyro data in the whole processes of AUV and DT experiments. After the effects of permanent and induced magnetization of platform were eliminated (Isezaki, 1986), magnetic anomaly generated from the magnetic target was clearly visualized.

2) Bosei-maru (Tokai Univ) Cruise (30 May - 05 Jun., 2010; Bayonnaise Knoll)

We carried out the DT survey in the inside and outside of Bayonnaise caldera (E139.75,N31.55). One FG sensor was set at the tail of the titan frame. The frame including the magnetic exploration system was towed by 50 m non-magnetized cable after the metallic wire along east-west track line at the depth between 500-550 m, which crosses just above the hydrothermal area known as Hakurei deposit.

3) Yokosuka YK10-17 Cruise (9-19 Dec., 2010; Bayonnaise Knoll)

We carried out the AUV (Urashima) surveys in the inside and outside of the Bayonnaise caldera. Three FG sensors were installed in the payload space of AUV, and one OH sensor was towed from the rear side of AUV by 25 m cable. In those dives, we used both optical fiber gyro set up in the payload space and INS (Inertial Navigation System) of AUV. The AUV was navigated at the altitude of some tens of meters and the depth of 500m to make three-dimensional models of hydrothermal deposit of Bayonnaise caldera.

From above cruises, we could understand the efficiency of our system, restrictions of navigation and their suitable operation, and the facts to be improved which are related to some kinds of noise components and combination of plural signals.

Acknowledgement:
We are grateful to the crews of R/V Yokosuka (Captains Mr. E. Ukekura in YK09-09, and Mr. K. Sameshima in YK10-17) and Bosei-maru (Captain Mr. H. Kawachi), who made our difficult trials in the navigation possible by their professional skill. We also thank to all scientific participants, marine crew, support staff, and technical experts of private companies for overall support. This project has been supported by the Ministry of Education, Culture, Sports, Science & Technology (MEXT) - Japan.

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Keywords: hydrothermal deposit, magnetic exploration, ocean bottom resources, autonomous underwater vehicle, deep-tow system, performance evaluation

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STT056-P05 Room:Convention Hall Time:May 26 16:15-18:45

Imaging of fault structure and fresh/salt water boundary in a coastal zone by electric survey

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Fault structures in coastal zones are important for disaster prevention and mitigation against large earthquakes that originate in latent fault movement in the sea areas, identification of flesh/salt water boundary, and evaluation of nutrient loads on sea environments associated with groundwater discharge. However, geological investigations in the coastal zones have not been much accumulated because of the difficulty in approaches. Then, we applied an electric survey method and using borehole data to clarify hydrogeologic structure in a coastal zone.

The Kumamoto Plain facing the Ariake Sea is well-known groundwater resource because of high mountains behind the plain such as Mt. Aso. Resistivity value is an important physical property of geologic media, which is related to porosity of rocks and soils. Chargeability is also an important electric property which is calculated from the temporal change of electric potential after stopping the current supply.

In addition to the traditional electric survey, we measured temporal resistivity change which were aimed at detecting inflow and outflow of groundwater (or seawater) in the sediments using the large difference in resistivity between seawater and groundwater. The measurements were carried out five times during 2007 to 2010 with 2D measurement lines of 150 m and 260 m lengths, using an equipments, Syscal-R2 (IRIS instrument) and multi electronode system. The measurement lines were set to be parallel and perpendicular directions to the coastal line.

By the inversion analysis of apparent resistivity and chargeability data, two fault lines along the extension of an active fault in the mountain and fresh/salt water boundary near the 20 m depth were detected from the temporal change of the resistivity. This boundary may originate from the groundwater flow along the fault line. Study area is divides into permeability zone of sand and non-permeability zone of clay. It is thought that groundwater and sea water moves along the pervious layer.

Keywords: Ariake Sea, Uto peninsula, chargeability, Resistivity

Japan Geoscience Union Meeting 2011
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STT056-P06 Room:Convention Hall Time:May 26 16:15-18:45

Development and Fundamental Experiments for Validation of Transmission-type Ground Penetrating Radar

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Visualization techniques of the subsurface structure using the electromagnetic waves have been used widely in many fields such as detecting underground pipe, investigation of existence of underground space and underground crack that can cause subsidence, excavation of archeological site, estimating geologic structure, and natural resource exploration. To improve the accuracy of visualization, estimation of subsurface physical properties such as dielectricity electric conductivity, and magnetic permeability is indispensable, which can contribute to identify the subsurface materials in addition to geometrical properties of material boundaries. However, it is difficult to estimate such subsurface properties at the present because of strong heterogeneity concerning physical properties distribution and shape of stratum boundary.

For this problem, we developed a prototype system of Ground Penetrating Radar (GPR) which separates transmission antenna and receiving antenna. A merit of this transmission-type GPR (T-GPR) is that the input signal can be received at the antenna more strongly than the traditional reflection-type GPR by reducing travel distance of radar by half.

Capability of the T-GPR was tested by a problem that it could detect caves in the ground under the water table. Simple ground model was produced using soils, water, and two types of pipes (vinyl chloride tube and Hume pipe) which were buried under the cave. These pipes were a model of actual drain pipe. Transmission antenna and receiving antenna were set on the surface and in the pipes, respectively. As the result, our T-GPR could detect the cave in the soils saturated with water regardless of the type of the pipes, which demonstrates the usefulness of T-GPR consequently.

Keywords: Ground Penetrating Radar, transmission, cave detection, drain pipe, saturated soil with groundwater

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STT056-P07 Room:Convention Hall Time:May 26 16:15-18:45

Laboratory experiment of rock's hydraulic conductivity evaluation using EK (Electro Kinetic) phenomenon

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It is very important to evaluate engineering properties of rock by using geophysical exploration methods. Especially, hydraulic conductivity is one of the most important engineering properties to investigate geological structure for high level radioactive waste disposal or carbon dioxide (CO_2) geological storage. However, measurement of hydraulic conductivity requires huge consumption times. So if hydraulic conductivity is estimated by geophysical methods cost-effectively, the measurement time will be reduced.

When elastic wave is propagated into rocks, small streaming potential is generated. This is called EK (Electro Kinetic) potential, which may have a correlation with hydraulic conductivity. Hydraulic conductivity can be estimated easily by measuring the potential of rock during propagation of elastic wave.

To verify the relationship between EK potential and hydraulic conductivity, we constructed the equipments to measure the EK potential of soil and rock samples, and conducted laboratory measurements. As a result, hydraulic conductivity was related to phase delay of EK potential by the measurements of soil samples. This suggests that hydraulic conductivity can be estimated by measuring the phase delay of EK potential.

Keywords: Hydraulic conductivity, Electro Kinetic phenomenon, Geophysical Exploration, Elastic wave, Phase velocity

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STT056-P08 Room:Convention Hall Time:May 26 16:15-18:45

Estimation of transfer function with long-period linear vibrator

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We have made experiments on accurately controlled seismic source based on the concept of ACROSS. Conventional source that are used in ACROSS are of rotational type, in which rotation of an eccentric mass generates centrifugal force. In spite of the simplicity of the principle, the conventional source has a shortcoming that the force in lower frequency is much smaller than that in higher frequency range because the force is proportional to the square of the rotational frequency. Seismic source with linear mass motion (linear vibrator) can overcome this shortcoming, which is essential especially for the region of high scattering characteristics. We made an experiment on the linear vibrator by courtesy of Kajima Corporation in Awaji ACROSS site to compare it with the rotational type vibrator, and confirm that we can obtain transfer functions with operational method of signal processing.

Based on the result, we made the next experiment on a linear vibrator in the area of dense seismic network, which are deployed by Oya Community Development Public Corporation at Oya town, Utsunomiya city. The purposes of the experiment are 1) comparison of the result in different geological condition with that of Awaji, 2) research on the effect of subsurface vacancy to transfer function, 3) verification of velocity structure that is used in hypocenter determination by the seismic network. The vibrator was deployed in a garage of Kawasaki Coop. at the northwestern part of the network. The vibrator was operated in perpendicular directions in the frequency range of 1.0 to 10.0 Hz with an interval of 0.2 Hz. It was operated for 29 minutes for each frequency. Transfer functions are obtained by the deconvolution with the acceleration of the mass on the vibrator. Unlike the rotational ACROSS source, the linear vibrator is not synchronized to GPS. Therefore the acceleration of the mass is recorded with a data-logger whose sampling timing is synchronized to GPS.

The signal is received continuously by 126 stations that are operated by Oya seismic observatory. All the stations are located within the distance of 3km from the vibrator. Each station is deployed with a velocity sensor of vertical component with the natural frequency of 14 Hz except for 11 stations, where three component sensors are deployed. We also deployed three component sensors with a natural frequency of 2.2 Hz at 7 stations in order to compare the signal with the existing sensors. The vibration just around the vibrator is also measured. All but for 6 stations can record the vibrations above the ground noise. At the poster, the transfer functions both with radial and transverse vibrations are presented.

Keywords: control source, vibrator, ACROSS, Oya, subsurface vacancy