Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

STT07-01 Room:421 Time:April 29 09:00-09:15

Applicability of fictitious domain method in data processing of marine CSEM exploration

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Marine controlled-source electromagnetic (CSEM) survey, one of the electro-magnetic (EM) sounding methods, is considered as a technique in practice for the exploration of hydrocarbon resources including methane hydrate (MH). In the analysis of EM field acquired in CSEM survey, forward modeling is used to model sub-seafloor structure. In the forward modeling, transforming the diffusive Maxwell equation to a fictitious wave domain reduces CPU time (Mittet, 2010). Phase velocities of electromagnetic waves are a function of material properties, i.e., electric conductivity and magnetic permeability. In the fictitious domain, the difference in the phase velocity as a function of materials is exaggerated so that EM field could propagate in the earth with much slower apparent phase velocity compared to the other field propagating through materials above seafloor. However, such character of the fictitious wave domain has not been well exploited for the estimation of subsurface resistivity structure. In the present study, we examine whether the received waveforms in the fictitious wave domain could highlight MH responses better than in the diffusive domain. We conduct numerical simulations using a three-dimensional resistivity model composed of seawater and earth layers, and a thin MH zone of a rectangular shape. Our results show that the sensitivity to the MH response in the received waveform is improved in the fictitious domain. It is mainly due to the separation of EM waves travelling with different phase velocities through the sub-seafloor layers and seawater in the fictitious domain. We then tested to see if the transform from the diffusive domain (e.g., observed EM field) to the fictitious wave domain is possible or not for further utilization of the transform. As a result of the singular value decomposition method to achieve the transform, the transforming EM waves in the fictitious domain indicated that the sensitivity to MH becomes about twice as much than the original EM field in the diffusive domain.

Keywords: CSEM, Fictitious wave domain, methane hydrate

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STT07-02 Room:421 Time:April 29 09:15-09:30

Subsurface imaging with EM migration of magnetic fields from multiple frequencies

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These days, the supply of water is facing a crisis due to the dramatic growth of population, industrialization, etc. As a result, the groundwater demand is becoming more and more stronger than before. Electrical prospecting is a method usually attempted for groundwater exploration, but setting the observation equipment in desert regions, where water shortage is a serious problem, causes us difficulty using this method there, since there is nothing that assures electrical contact between electrode and the earth. In these circumstances, some other methods that do not require any contact of electrode are needed. VLF or ULF is the method that satisfies the condition. However, none of these methods could provide information necessary to locate groundwater and it is strongly necessary to locate water head of survey areas. There is some shortcomings in the present processing of these VLF and ULF data. In this study, the phase-shift method, which is used in seismic migration, is applied to the horizontal magnetic components with multiple frequencies in order to image subsurface resistivity structures to locate groundwater. The survey is conducted more easily and shortly, if only the magnetic sensors above the surface are enough for estimating the structures. As in the seismic migration, both upward/downward imaging and the exploding reflector concepts can be applied to the horizontal magnetic components. The synthetic data examples show that the migration method is effective for imaging the conductive anomaly. However, it is necessary to select appropriate frequency bands in order to estimate correct subsurface structures. We conclude that this technique gives an approximate resistivity structures quickly and that the migration of magnetic components is expected to provide information on the subsurface. This method is also useful for geological interpretations and for an initial model of the more complicated inversion method.

Keywords: electromagnetic exploration, migration, apparent resistivity structure

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STT07-03 Room:421 Time:April 29 09:30-09:50

Application of particle method to forward modeling of marine controlled-source electromagnetic survey

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A new marine controlled-source electromagnetic (MCSEM) forward simulation is presented in this study. The benefit of the method is the better treatment of complicated seafloor topography and/or buried structures than before. Here, we focused on the moving particle semi-implicit (MPS) method. In our method, the Maxwell ' s equations are discretized with particle arrangement without grid structure, which is usually used in finite-difference method (FDM). Each particle denotes the three components of electromagnetic fields at each particle. MPS method has some advantages over the other methods such as finite-element method (FEM), FDM, integral method (IE), etc. An obvious advantage of this approach is a numerical model that can flexibly form arbitrary topography shapes. Although FEM is sometimes employed to treat the topographic structure, especially for MCSEM, pre-process for creating grid or mesh structures require a time-consuming procedure especially in three-dimensional cases. A second advantage is that the three components of electric field and electric current as well as magnetic field and source are defined at the same location of every particle, while not at the same location in the case of Yee ' s grid.

We tested our three dimensional MCSEM forward simulation using the particle method and confirmed that the accuracy of the forward simulation with the simple tilted layered model would be improved. Our forward modeling results show the accuracy sufficient to discuss with the analytical results. The local and arbitrary refinement of particle is conducted to obtain more accurate result using the same model. The local refinement is applied only near the transmitter and receiver dipoles. The accuracy of MPS becomes higher in the local refinement than in the use of isodiametric particles. Our results suggest that the method using MPS with locally refined particles is useful for the forward simulation of electromagnetic field with arbitrary topography in the MCSEM modeling.

Keywords: Marine controlled-source electromagnetic, Forward simulation, Particle method

STT07-04 Room:421 Time:April 29 09:50-10:10

Simultaneous inversion of self-potential for estimating hydraulic parameters and streaming current coefficient

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In this study, we develop an inversion scheme for the simultaneous estimation of hydraulic conductivity, streaming current coefficient and specific storage, using transient self-potential (SP) data. SP is a natural electrical potential, which is thought to be caused by subsurface fluid flow through the electro-kinetic coupling. Recently, several SP measurements are performed during pumping tests to characterize the parameters of the aquifer. Almost of all SP analysis methods are adaptable to the static SP data, but a huge amount of the transient SP data is not used efficiently. Therefore, we develop an inversion scheme for the analysis of transient SP data. The electrical conductivity, streaming current coefficient, hydraulic conductivity and specific storage are parameters effectively influencing the SP profile on the surface, and can be solved in the inversion. The distribution of electrical conductivity structure can be used if the electrical resistivity tomography (ERT) or other EM measurements are performed with the SP measurement. We employ the relationship between hydraulic conductivity and streaming current coefficient to decreases the number of estimating model parameters, and to enable the simultaneous estimation of hydraulic conductivity and streaming current coefficient. First in this study, we check the sensitivities of the hydraulic conductivity and specific storage obtained at different times. The sensitivities of the hydraulic conductivity and specific storage are different with respect to the phase. The simultaneous inversion of hydraulic conductivity and specific storage from the transient SP profile is turned out possible from the difference in phase. Finally, we apply our inversion scheme to a synthetic SP profile, and reconstruct the subsurface structure of hydraulic conductivity, streaming current coefficient and specific storage simultaneously. As a result, our inversion technique allows us to obtain the hydraulic parameters from SP data on the ground surface, although the conventional hydraulic tomography strongly relies on the borehole data.

Keywords: Self potential, Inversion, Time domain, Hydraulic conductivity, Specific storage, Streaming current coefficient

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STT07-05 Room:421 Time:April 29 10:10-10:25

Numerical study for failure behavior of rock masses including complex free-surfaces using a particle method

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Failure of rock mass including complex free surfaces is of importance in many engineering and scientific fields. This paper applied an advanced discretization approach to simulate quasi-static failure of rock mass within a Hamiltonian particle method (HPM) framework. In HPM, a free surface is introduced in a simple way, just by removing or ignoring outer particles. This potential can be developed to discretize numerical models including complex free surfaces without the increment of time for pre-processing. In the present study, we developed the numerical simulator based on HPM with a staggered particle technique for simulating brittle failure and AE activities in rock mass with incorporating the elasto-plastic damage model. We, first, conducted uni-axial compressive tests for validating the effectiveness of our approach. Next, we adopted rectangular and circular disc specimens with a hole as complex free surface models. Our numerical results had good agreement with those from laboratory experiments. This suggests that HPM would be a method to simulate failure behavior of rock mass without time-consuming pre-processing.

Keywords: particle method, failure behavior, rock mass

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STT07-06 Room:421 Time:April 29 10:25-10:40

Forward calculation of Magnetotelluric responses with MPS method

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In this research, we developed a new 2-D magnetotelluric (MT) forward simulation method based on the MPS (Moving Particle Semi-implicit) method framework. Our final purpose is to calculate MT response with arbitrary three-dimensional topography.

The MPS method is a particle method and was first developed for the simulation of incompressible fluid flow (Koshizuka and Oka, 1996). Recently, the MPS method is used the digital reproduction of failure of materials,for the simulation of elastic wave propagation, etc. We use the MPS method for the simulation of electromagnetic induction.

In our forward calculation, electric and magnetic fields are defined at each particles in a calculation model. MT responses are calculated on the surface of the ground with topography with a horst-graben shape. Our simulation results indicate that MT forward calculation with the MPS method is suitable for free surface like topography, because the MPS method does not require the mesh configuration such as for FDM and FEM, particles in the MPS method could form any shape. The results of MT forward calculation (TE-mode and TM-mode) based on MPS method is reliable enough to calculate MT responses on models with topography. Based on the inherent character of MPS method, the expansion of our code from two-dimension to three-dimension will be easily achieved.

Keywords: Magnetotelluric, MPS, topography

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STT07-07 Room:421 Time:April 29 11:00-11:15

Fluid-physical simulation of silicate scale formation using lattice Boltzmann method

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Scaling behavior has an important role in various geosciences fields. For example, precipitation of silica can cling to pipes and wells, and prevent the geothermal power generation. Silica precipitation strongly affects the circulation of hydrothermal systems by changing the permeability structure, which is related to the nucleation of seafloor massive sulphide. Self-sealing is of importance in the understanding of long-term radionuclide mobility and the safety of deep geological repositories of radioactive waste.

The deposition of amorphous silica is controlled probably by many processes. There have been a number of experimental studies made on the chemical kinetics of silica deposition as a function of the degree of super-saturation. However scaling estimated by the simple chemical precipitations cannot explain the measured features in laboratory and field experiments. On the other hand, a high rate of deposition could be found where fluid flow stagnates. Although it has been empirically observed that the fluid flow structure can influence silica scaling, relatively little research have been conducted to investigate hydrodynamic effect on silica scaling. The aim of this work is to evaluate the importance of both chemical kinetic and hydrodynamic effects on silica scale growth with a method of numerical simulation.

Here using the lattice Boltzmann method, we calculated velocity, temperature and concentration of dissolved silica in the 2D parallel plate channel and predicted the silica deposition of both chemical kinetic and hydrodynamic deposition processes. The laboratory results by Hosoi and Imai (1982) can be as the reference. We also predicted the silica deposition along the channel with sudden expansion of width. For the latter case, the similar field example in the production pipes of the geothermal well was reported (Mercado et al., 1989).

In our numerical simulations, the silica deposition predicted by the kinetic process has the magnitude extremely lower than the amount of laboratory experiment, but shows the similar magnitude if the hydrodynamic process is considered for scaling. In addition, at the another channel model with the sudden expansion scaling predicted by the hydrodynamic process can explain the observed feature at the geothermal well.

It is found that consideration of the simple kinetics process solely is not sufficient for explanation of the real silica deposition. Therefore, we emphasize the importance of hydrodynamic effect on silica scaling. To predict the silica deposition more quantitatively, an advanced-simulation including behaviors of colloid silica particles in flow.

Keywords: scale prediction, silica scaling, kinetics, hydrodynamics, the lattice Boltzmann method

STT07-08 Room:421 Time:April 29 11:15-11:30

Distinct element method for solid-fluid coupled interaction in the application of hydraulic fracturing

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The hydraulic fracturing is of great interest in many scientific and engineering fields in hydraulic fracturing, such as the hot dry rock geothermal power(HDR). However, the natural fractures have significant influence on the nucleation and growth of fractures created in hydraulic fracturing. In addition, the viscosity of fluid used in hydraulic fracturing also influences the geometry of hydraulically created fractures. Although the influence of both natural fracture and fluid viscosity has been intensively investigated on the distribution of hydraulic fractures, none of the studies has dealt with natural fractures and fluid viscosity at the same time and the interaction between them has not been revealed yet. We, therefore, performed a series of numerical simulations for hydraulic fracturing in naturally fractured rock using a 2D flow-coupled DEM code to examine the influence of the fluid viscosity on the interaction between hydraulic and natural fractures. In this study, a low viscosity fluid of 0.1 m^2/s and a high viscosity fluid of 100.0 m^2/s are used. Our model is a square block with a borehole at the center under a stress field whose maximum and minimum stresses are 10 and 5 MPa, respectively. We apply the hydraulic pressure to the borehole wall, and observe how induced hydraulic fracture would propagate in the presence of a single natural fracture located adjacent to the borehole. The viscosity of fluid and the angle between the maximum stress direction and fracture orientation are the parameters of the numerical simulation. The results show that the lower the oblique intersection angle is, the less linearly the induced fracture crosses the pre-existing fracture. However, when a high viscosity fluid is used, the interruption of natural fractures decreases and the induced fracture tends to go straight along the direction of maximum compression. Our numerical example implies that high viscosity fluid could be used in hydraulic fracturing to reduce the influence of a natural fracture when the hydraulic fracture intersects the pre-existing fracture with certain angles .

Keywords: hydraulic fractureing, viscosity, natural fracture, discrete element method

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STT07-09 Room:421 Time:April 29 11:30-11:45

Numerical simulation for apparent viscosity change under oscillating boundary condition using lattice Boltzmann method

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Unsteady fluid dynamics in Newtonian and non-Newtonian fluid is the main concern of aeronautical engineering, mechanical engineering, chemical engineering, resource engineering and civil engineering. It is also true to the oil industry because the amount of oil production in the world is decreasing recently, it is of importance to seek the technological development for enhanced oil recovery (EOR) in place in the subsurface. Recently, many laboratory experiments and field tests have been performed such as water, gas, chemical, or thermal injections to attempt the enhancement of oil production. Seismic stimulation is known as one of the EOR methods and unsteady flow problem. Numerous observations show that seismic stimulation of oil reservoir may improve oil production. However, for effective usage of seismic EOR, we need to understand the characteristics of changing apparent viscosity under oscillating solid-phase. In this study, we attempt to demonstrate the apparent viscous change in laminar flow under oscillating boundary condition with the models of single pore throats and porous media.

We use Lattice Boltzmann method (LBM) describing Boltzmann equation. We use 2-dimensional 9-velocity (2d9v) model to simulate 2-dimensional incompressible viscous flow. We assume that the background pressure difference between inlet and outlet is constant. The flow is generated by a constant pressure difference.

We discuss the apparent viscosity of a single pore throat and porous media.

First, we discuss four characteristics of an incident elastic wave: amplitude, frequency, angle, and pressure disturbance (P wave). The characteristics of amplitude, frequency and angle are largely related with the amount of changing apparent viscosity. The flux increases under cases with large amplitude, high frequency, and large angle (S wave) of incident to the wall. On the other hand, the pressure disturbance (P wave) is not effective for changing apparent viscosity. We then discuss the possibility of changing apparent viscosity in terms of fluid properties. Wall oscillation can cause improving relative permeability. So, if the rock has water wettability, the oil flux largely increase with wall oscillation. After that, we examine the possibility of changing apparent viscosity in terms of pore scales or shapes under the oscillating boundary condition with LBM. The models of single pore throat consists of two half pore and one pore throat. The models of porous media consist of several pore spaces connected by pore throats from one pore to the others. The shapes of single pore throats are also largely related with changing apparent viscosity. The apparent viscosity decreases with increasing length of the pore throats and radius of the pore throats, and with decreasing width of the pore throats and large pore radius. Comparing single pore throat model and porous media model, we find the apparent viscosity change in porous media models cannot be replaced by linear combination of the apparent viscosity changing in single pore throat models.

Our numerical results imply: i) the flow resistance under oscillating condition increases because the velocity difference between the wall and the center of flow is larger than that in steady flow, ii) the effect of the advection term in oscillating boundary condition is larger than that in steady flow, iii) fluid extrusion is generated by partial pressure gradient near the wall and pore throat, and iv) the oscillating boundary may cause improving pressure loss.

Keywords: Lattice Boltzmann method, Unsteady flow, Seismic EOR, Apparent viscosity, Pore throat scale

STT07-10 Room:421 Time:April 29 11:45-12:05

Estimation of stress change in ductile part of the crust inferred from seismic scattering

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In the past, stress field in the subsurface has been measured by various techniques. For example, the borehole-breakout, the stress release method, the hydraulic fracturing, the strain gauge buried in the ground are used to measure the stress field after costly drilling the subsurface. Beside the techniques requiring direct access to the subsurface, the stress field is also measured indirectly. The Electro Distance Meter, the Global Positioning System, etc. are used to measure a surface deformation in time, from which the subsurface stress change is estimated. However, the estimated stress change in the subsurface is largely affected by near-surface inhomogeneities. Thus, information on the stress field should be obtained from other indirect techniques.

Here, we focus on seismic scattering wave, particularly the coda-Q value, to measure spatial and temporal variations of subsurface stress field. The coda-Q, derived from the attenuation of coda envelope, is perceived to be an indicator of the inhomogeneity in the subsurface. Meanwhile, it has been proposed that the coda-Q has a proportional relationship with the magnitude of stress using a numerical simulation. In this study, we hypothesize that the coda-Q, obtained from seismic waves traveling over a wide range of the crust, indicates stress change in a deep subsurface. At first we numerically calculate a relationship between the coda-Q and the magnitude of stress using a homogeneous crustal model, and show that the coda-Q systematically increases against the magnitude of the stress. Then we confirm the relationship using a heterogeneous numerical model, which has a low velocity zone near the surface. It is revealed that the coda-Q indicates the magnitude of the stress change in the deep subsurface, beneath the inhomogeneity, while the surface strain distribution is largely affected by the low velocity zone near the surface. For the next step, using real seismic data acquired at the regions of the 2008 Iwate-Miyagi Nairiku earthquake and the 2004 mid-Niigata prefecture earthquake, we examine whether the coda-Q indicates stress change in the deep subsurface. The stress change estimated from the coda-Q corresponds with the theoretical one in the ductile part, calculated by a fault model acquired by a seismic wave analysis, whereas the estimated stress change dose not correspond with the inferred one from GPS measurement. It means that the coda-Q can indicate stress change in the deep subsurface, which could give more accurate investigation than the GPS measurement.

Keywords: seismic scattering, stress change, ductile, heterogeneity

STT07-11 Room:421 Time:April 29 12:05-12:25

2D simulation of seismic wave propagation for time lapse monitoring of heterogeneous structure and near-surface effects

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For the time lapse study in CCS and EOR, we have proposed the method using the seismic ACROSS (Accurately Controlled and Routinely Operated Signal System) and geophone array. However, it is considered that the near-surface effects and their temporal changes caused by water content changes, temperature and surface wave generation, might have very large effects for time lapse estimation, and we would like to evaluate and reduce the near-surface effects by the comparison of surface and borehole geophone records. We have carried out simulation studies to evaluate the effects of near-surface and heterogeneities such as the man-made cavities in the green tuff layers (Vp ~2.5 km/s). We also evaluate the near-surface effects by changing geophone depths. The results of the simulations are as follows.

At the simulation of surface hypocenters, seismic waves passed through the man-made cavities attenuated and seismic waves scattered at the man-made cavities. This shows that there will be a heterogeneous structure like man-made cavities when observed seismic waves were attenuated, and the man-made cavities will become a secondary hypocenter.

As the results of simulation of surface hypocenters, the amplitude of scattered waves observed by borehole geophones were larger than that of surface geophones. This means that the borehole geophones are suitable for time lapse monitoring of heterogeneous structures. The amplitude of scattered waves observed by horizontal components of geophones was larger than that of vertical components of geophones. This means that the horizontal components of geophones are suitable for time lapse monitoring of heterogeneous structures.

At the simulations of deep hypocenters (15Hz, 2Hz) as assumed natural earthquakes, seismic waves scattered by the man-made cavities. Observation of natural earthquakes will be helpful to look at the wide seismic structure.

STT07-12 Room:421 Time:April 29 12:25-12:45

A time lapse test of seismic waveform changes during several days at the green tuff area in Japan using a seismic vibrat

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In order to estimate the physical property changes in the subsurface, the time-lapse measurement is quite useful for various cases such as CCS (Carbon Capture and Sequestration) zone, EOR, shale gas exploration, and oil production. The authors have carried out the time lapse experiment at the water pumping area in Kingdom of Saudi Arabia using a very accurate and extremely stable seismic source called ACROSS (Accurately Controlled and Routinely Operated Signal System).

Because this seismic ACROSS has been installed semi-permanently at the Saudi test field, it is not easy to bring to any places. Instead, we alternatively used a much conventional electro-magnetic vibrator for this field test in the green tuff area in Japan.

We used the vibrator for 12 hours a day during five days in 2013. We also used 110 geophones and two borehole geophones placed just above the green tuff miming area with 2km x 3km. We used sweep signal from 10 Hz to 50Hz during 100 second.

We repeated 32 sweep during an hour. 32 stacking of waveforms of 100s second time-windows improved the S/N, and we can identify arrivals up to 3 km distance by this one-hour stacked data. If we look the 12 hours waveforms, it is difficult to find the change of those with time.

Using the subtraction of waveforms every day with 12-hour stack data from the first day, we generated residual waveforms. If we use residuals waveforms from the first day, we can clearly identify the change of waveforms with time. In conclusion we can use the time lapse method during five days by the use of residuals waveforms though the period is short. We can use conventional seismic vibrator(s) for the time lapse for several days.

Keywords: time lapse, ACROSS, seismic method, residual waveforms, vibrator source, green tuff

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STT07-13 Room:421 Time:April 29 14:15-14:30

A Reflectivity Guided Elastic Full Waveform Inversion

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Full Waveform Inversion (FWI) of seismic reflection data has become a common technique for producing subsurface images based on local minimization of least squares misfit between observed data and calculated model. Usually, an initial model that is close to the global solution of the problem is needed to obtain satisfactory results without being trapped in a local minimum of the misfit function. Due to the limitations in quantity of the observed data, e.g. using seismic traces from surface receivers to make an image of earth model, the full waveform inversion problem is ill-posed and underdetermined. The problem becomes even worse when dealing with elastic waveforms which require increased number of model parameters, i.e. P wave velocity, S wave velocity, density etc. In order to overcome this problem, inserting a priori model information in to the inversion process helps the algorithm to converge to a solution in the vicinity of the global minimum. This kind of information could be included in the gradient of the misfit function by adding model terms, when using conjugate gradient method to iteratively update the model parameters.

On the other hand, producing reliable velocity model is a key for successful Pre Stack Depth Migration (PSDM) of seismic data. Assuming an available depth section of seismic reflection data, e.g. by time to depth conversion of time migrated section, we estimate the P wave velocity from seismic section by first extracting reflectivity and then using Gardner equation (Gardner 1974) as stated by Hondori et. al 2013. This will produce a P wave velocity model which is used in full waveform inversion as a priori information. Our frequency domain elastic full waveform inversion is developed using finite difference method and perfectly matched layers are used on the boundaries of the computational area. A preconditioned conjugate gradient method is used together with improved pseudo Hessian matrix for updating the model parameters. At each iteration the gradient is calculated using adjoint state method, and then l_2 norm of the model term is added to the gradient to constrain the inversion. We suggest that this method not only improves the full waveform inversion results, but also resulting FWI models provide a good velocity model for pre stack depth migration of seismic data.

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Keywords: Full Waveform Inversion, Frequency Domain, Elastic, Reflectivity

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STT07-14 Room:421 Time:April 29 14:30-14:45

3D-FDFD simulation for high resolution eddy-current testing method

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The applicability and the feasibility of eddy-current testing method for the measurement of wall thinning and surface crack of steel structure have been practically confirmed by field and laboratory experiments. Where and how large the cracks would be are roughly understood by this method. However, it is difficult to estimate the exact size and shape of them. For more accurate inspections, there has been a growing demand to quantitatively evaluate the cracks. Therefore, we have developed a numerical simulator for the high accuracy eddy-current method. Eddy-current method measures excitation magnetic and induced magnetic fields, the latter of which is caused by the eddy-current in the inspecting material. In order to calculate induced magnetic field deformed by the cracks, we used three-dimensional finite-difference frequency domain technique to solve Maxwell's equations numerically. As a simulation model, two-layer structure consisting of seawater and steel plate including cracks is used. We simulated a variety of cracks to estimate characteristic of the induced magnetic field, and compared the results in terms of what kind of difference in the induced field would appear. As a result, the effect of surface cracks of steel plate on receiving magnetic field intensity was confirmed as follows: the induced magnetic field intensity increases near the edge of cracks and decays above the cracks with the distance to the edge. The deeper and wider cracks are, the more the magnetic field intensity becomes attenuated. Due to the limitation of our simulation schemes, the response of magnetic field intensity whose detectable scale of cracks was no smaller than mm order. We are introducing a method that could allow us to confirm much finer detectability.

Keywords: NDI, Maxwell's equations, Eddy Current, numerical simulation

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STT07-15 Room:421 Time:April 29 14:45-15:00

Elastic parameter estimation in full waveform well-to-well tomography

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Seismic full-waveform inversion (FWI) method has been used to estimate velocity and density structures in the subsurface. The waveform analysis is a powerful tool to investigate the properties in the areas of interest, and the importance to use the waveform is widely recognized in the seismic explorations. As the wave propagation is influenced by elastic parameters, Vp, Vs, density, it is necessary to include these parameters in FWI (Virieux and Operto 2009). However, there are few previous studies dealing with density as a parameter in the application of elastic FWI. Density is usually estimated using an empirical formula such as Gardner's relationship (Gardner et al., 1974), or is fixed to a constant value. Almost all elastic FWI studies have neglected the influence of approaches how density parameter is estimated. The objective of this study is to investigate how difficult the estimation of density structure is, and propose a new approach to overcome the problem. We employ 2D numerical simulations in order to investigate the important factor in the inversion of density structure. Our results show that it is difficult to estimate density structure because density structure is less sensitive to waveform than Vp and Vs. Therefore, we hypothesize that the simultaneous inversion of Vp and density structures, using a selected dataset can improve the accuracy of the FWI. For testing this hypothesis, various ways for estimation of Vp, Vs and density using different datasets and approaches. We conclude that Vp and density structures should be estimated simultaneously in the elastic FWI, in which P-wave data separated from the seismic records is used as the input data.

Keywords: full-waveform, tomography, density

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Estimation of fluid contact in terms of attenuation

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Sonic logging has been widely used for many years to acquire physical properties of formations in the vicinity of hydrocarbon reservoirs. When gaseous phase exists in the formation fluid, the compressional waves traveling through the formation could be strongly attenuated due to low bulk modulus of gas in the fluid, while the shear waves are not. For acquiring physical properties of fluid in the formation, Biot physics or poroelastic analysis would be the best method. Among the available technologies, quality factors based on the Biot's equation could be used. Although the Biot's theory considers the viscous attenuation induced at the interface between pore wall and fluids, the intrinsic attenuation caused by the internal friction in the matrix is ignored.

In the present study, adding the intrinsic attenuation we investigate if we take the effect of the viscous attenuation from the acquired quality factor, and then, on the basis of the result, if we estimate the fluid contact (e.g. gas-oil contact and oil-water contact). We employ a 2D finite-difference scheme to simulate seismic wave propagation in a poroelasic medium. The intrinsic attenuation is included in our model using a filter for frequency-independent quality factor (constant-Q). We then achieve the results of compressional and shear wave in our numerical simulations. Our results show that on compressional and shear waves, obtained the quality factors different from each other. We acquire the effect of the viscous attenuation by subtracting the quality factor of shear wave from the quality factor of compressional wave. We conclude that the effect of viscous attenuation is extracted and the gas-oil contact is estimated.

Keywords: Q, attenuation, poroelastic, Biot, sonic logging

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AVO waveform inversion for estimating the fluid contact with fluid transition zone

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The fluid distribution in the hydrocarbon reservoir affects waveforms acquired in reflection seismic method. A reflected wave changes its waveform at the transition zone of the interface of two different fluids as a function of volume fraction of the two. AVO is in general used to estimate the difference in the P and S wave velocities for the interfacing two media at the interface without any assumptions on the existence of the transition zone. The consideration of the effect of the volume fraction of a fluid to the other in the waveform could be a key for evaluating the fluid mixture around the fluid contact in the reservoir. Therefore, we try to use the waveform directly to estimate fluid distribution in the transition zone that has not been done in the practice of AVO.

In our research, we consider the effects of the transition zone at a gas-water contact (GWC) in a horizontally stratified medium on seismic waveforms. The numerical simulation reveals that the fluid distribution of transition zone distorts the seismic waveform both in amplitude and in phase. Then we use the difference in amplitude and in phase for estimating some necessary parameters expressing the fluid-mixture. We apply a waveform inversion method to the fluid substitution problems to see if the method is applicable to estimate the fluid contact with the transition zone, while the conventional AVO only utilizes the amplitude derived from observed data. Our numerical approach uses full waveform and the results imply the advantages in the estimation of the parameters including the thickness of the transition zone under that assumption of linear trend in the volume fraction in a contrast porosity condition. We suggest that the phase information should be used simultaneously for the inversion process to get the closer contact image.

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The insulation effects caused by the scattering of electromagnetic waves by fine spheres against insolation heating

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The temperature of materials rises when they are exposed to the sunlight (insolation heating). Insolation heating could be suppressed when the materials are coated with paint admixed with fine silica spheres (insulating paint). By coating buildings' walls and roofs with such paint, the temperature in the subjacent rooms could be kept lower thanby coating with regular one. The temperature of the former could be enough low so that no air-conditioning becomes necessary even in the mid summer. These phenomena are well known in a practical manner and have been widely utilized. However,the cause of the phenomena has hardly been analyzed theoretically yet. Moreover, micron-scale ceramic spheres have been known as the best commixture than the other metallic commixture of the same size. Theoretical analysis would greatly enhance the effects of the suppression of insolation heating. We focus on the light scattering by fine spheres under the assumption that the scattering of lights, i.e., electromagnetic waves, attributes to suppression of insolation heating and that the imaginary part of scattering coefficients of the spheres is a key to explain the observed phenomena. In this study, we therefore consider commixture sphere materials to be (i)silica, (ii)aluminum and (iii)copper, distributed in a paint layer coating an iron material, and calculate transmission, reflection and absorption coefficient using the Monte Carlo ray tracing method based on the Mie theory. Using these coefficients, the rise in temperature of surface of the iron layer would be estimated. We finally investigate how the structure of the paint attributes to the insulating effects.

We assume three layers: air, paint, and iron, and commixed fine spheres in the paint layer using Distinct Element method (DEM). A number of photons vertically incident to the paint at random position from the air. We then count the number of photons that reaches the iron to estimate the intensity of the transmitted wave, and count the number of photons that are absorbed by spheres to estimate the intensity of the absorbed wave energy. Fresnel Equations are used to identify photons' behavior stochastically using a random number. Moreover, Mie theory is used to calculate the radiation pattern of scattering at each sphere when a photon incident to the sphere. As a result, it is estimated that the transmission coefficient would be less than 0.1 forthe commixture material of silica whose radius is smaller than ca. 0.7 micrometers. On the other hand, the transmission coefficient could be much less than 0.1 if we use conductive spheres. However, in the latter case, the absorption coefficient would be approximately 0.5, which could cause the rise in temperature of the spheres and the paint.

We estimate the rise in temperature of iron layer using coefficients calculated above. Near-infrared radiation of the sunlight is assumed to be the incident wave. As a result, whereas the temperature would be 63 degrees Celsius if no paint is coated. On the other hand, the temperature would be suppressed to 39, 59 or 56 degrees Celsius, respectively, if we use silica, aluminum or copper spheres of the same radii of 0.5 micrometers. The metallic commixture could lower the temperature rise but the absorption of the energy seems deteriorate the efficiency of the insulation.

In conclusion, silica is one of ideal material for insulating paint in contrast with conductive ones such as aluminum and copper, mainly due to the absorption phenomena of electromagnetic waves by spheres.

Keywords: mie scattering, monte Carlo Ray-tracing, insulating paint, sphere, electromagnetic scattering