Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG15-01 Room:203 Time:May 24 15:15-15:35

Electromagnetic fields in the solid material neighbouring porous media

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Numerous studies reported that there are electromagnetic(EM) wave-fields associated with seismic waves. The electrokinetic effect, as one of the most possible mechanisms resulting in the coupling between the seismic and EM wave-fields, has attracted wide attention in the area of seismoelectromagnetism. The numerical experiments have confirmed that a finite fault in porous media can induce seismoelectromagnetic signals. The characteristics and the magnitude of amplitudes are consistent with those observed in natural earthquakes. However, all the used models consist of porous materials. In this work, we carried out numerical experiments to investigate the situation in the layered model composed of solid and porous materials together. It is found there are two kinds of EM waves in the solid material, the homogeneous and inhomogeneous EM waves. The former one is generated by the direct EM waves radiated from the source or the normal incident seismic waves at the interface between the solid and the porous media. The latter one is generated by the oblique incident seismic waves whose horizontal wavenumber is greater than the EM wavenumber in the solid media. The inhomogeneous EM waves propagate in the horizontal direction and decrease when the distance to the interface increases. For the solid area which is close to the interface (e.g., within 200m), the inhomogeneous EM waves behave very simliar with the co-seismic EM signals in the pure-porous model.

Keywords: electrokinetic effect, the coupled seismic and electromagnetic fields, solid material neighbouring porous media, converted electromagnetic waves generated at the interface

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SCG15-02 Room:203 Time:May 24 15:35-15:50

Exclusion of metal contact noise in the experiment of radio wave emission due to rock fracture

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1. Introduction

Formerly, the radio wave emission due to rock fracture was found at the frequency of 300 MHz to 22 GHz [1]. This phenomenon gathered much attention, as a possible tool to measure or even to predict a rock fracture in nature, which may be an earthquake or volcanic eruption [2] [3].

On the other hand, it was confirmed that radio waves were generated when metallic parts in the experiment system collided each other [4]. It is inferred to be caused by electric discharge due to charging effect of metallic parts by contact or collision [5]. Therefore, it is absolutely needed to discriminate these signals that were not originated by rock fracture itself.

Recently, we have remodeled the experiment system, of which all metallic pars are electrically shorted. Accordingly charging effect of the metallic parts is prevented in the rock fracture process. This paper describes the constitution of the experimental system and measured results.

2. Experimental system

The experimental system is composed of a destruction subsystem and a signal detection subsystem. The destruction system consists of a hydraulic pressing machine, a base plate, a ceiling plate, connecting poles, bolts and nuts. Theses all parts are connected with 24 twisted wires of 5 mm width and 1 mm thickness and with 9 twisted wires of 2 mm width and 0.5 mm thickness by screwing or soldering.

The signal detection subsystem is the same as the former one [4]. At each frequency of 1 MHz-, 300 MHz-, 2GHz-, and 18 GHz-bands, an antenna, a low noise amplifier and a filter are installed. The destruction and emission phenomenon is instantaneous so that a special recorder and a triggering system to activate a main memory are inevitable.

The rock specimens were quartzite, granite, gabbro, and basalt.

3. Measured results

We obtained the following results.

(1) In all rock cases, radio wave at 300 MHz was observed simultaneously with the destruction.

(2) Especially, in the case of quartzite, a weak 18GHz signal was observed in addition to a strong 300MHz. These signals occurred simultaneously.

(3) Cylinders of mortar were used as a specimen. But signal was not detected.

(4) When the rock debris, a laid blue sheet or a vinyl cover touched each other, radio waves were observed. The generated frequencies are strong 300MHz, weaker 2GHz, and the weakest 18 GHz, as is different from the case of rock fracture. The cause of the emission is esteemed to be charging and subsequent discharges.

(5) In particular time, we observed noises from environment. The signals, however, do not include 2GHz nor 18 GHz components.

4. Conclusion

All metallic parts in the destruction subsystem were electrically shorted to prevent emission due to discharge. Even so, radiation was observed in various rock cases so that the emission due to rock fracture is confirmed.

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Keywords: rock fracture, radio wave, metal contact, noise, parts, short

Japan Geoscience Union Meeting 2015
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SCG15-03 Room:203 Time:May 24 16:15-16:35

Medium effect on the characteristics of electromagnetic signals accompanying with seismic waves

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Recently developed numerical simulation technique can simulate the coupled seismic and electromagnetic signals for a double couple point source or a finite fault planar source. Besides the source effect, the simulation results showed that both medium structure and medium property could affect the coupled seismic and electromagnetic signals. The waveform of coupled signals for a layered structure is more complicated than that for a simple uniform structure. Different from the seismic signals, the electromagnetic signals are sensitive to the medium properties such as fluid salinity and fluid viscosity. The results may provide some insights of understanding the difference in the detectability of co-seismic electromagnetic signals in different geological regions.

This study is supported partially by the National Natural Science Foundation of China (41025014) and the National Basic Research Program of China (2014CB845903).

Keywords: Electrokinetic effect, co-seismic electromagnetic signals, medium effect, a double couple point model, a finite fault planar model

Japan Geoscience Union Meeting 2015
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SCG15-04 Room:203 Time:May 24 16:35-16:50

Properties of seismo-electric variations induced by microcracks in the nucleation stage of earthquake occurrence

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Characteristics of dominant three phases (P_f, S, EM) of seismoelectrical waves have been investigated using waveform which are suggested to be induced by microcrack in the nucleation stage of the 2011 Tohoku Earthquake (Fujinawa *et al*., 2013). Twelve B-type events having clear P, S phases and apparent EM phase with dominant frequency 500 Hz have been selected from the catalog of B type events. Slight traces of EM phases are searched at around the origin time. We estimated focal distances of those events using S-P time assuming the P and S wave velocity, which are corrected on the basis of arrival time of the identified EM phase. The corrected velocities are well in agreement of the measured logging data at the borehole. The accumulated number of events is found to follow the Gutenberg- Richter relation with the b ?value equal 0.7, indicating that the B-type events are of natural micro-earthquake. We can conclude that the seismoelectric mode of the SES related with natural earthquake can be observed by using high sensitive sensor.

The electric strength of fast- P, S, and EM modes of the shear tensile type events are compared with each other. Averages of observed amplitude order as As >Apf >Aem, which is partly different from those of previous numerical simulations (*e.g*., Gao and Hu, 2010). Those amplitudes are analytically estimated on the basis of the seismo-electromagnetic formulation of Pride (1994) assuming the isotropic homogeneous medium filled with confined solvent. The force field is the double couple model of Gao and Hu (2010) in consistent with the hypothesis that the source is microcrack. The typical value for physical parameters of elastic material, solvent and the streaming coefficient for seismic frequency result in the ordering Apf >As >Aem, a little bit different from the observational result. The contradictory relation between the observed result and numerical simulation may be attributed to the assumed whole space model other than the half space model.

Overall agreement between the observed and estimated results suggest that, 1) pulse-like events of B-type detected before the Tohoku Earthquake are induced by rupture of microcrack in the nucleation period of main shock, 2) observed phases of waveform (P_f, S, and EM) are corresponding to co-seismic Pf, S and free electromagnetic wave in the unified formulation, 3) the SES phenomena in the field can be analyzed by the formation.

Precursory phenomena of earthquake have been investigated by analyzing seismic activity, crustal deformation, groundwater anomalies, and electromagnetic anomalies. Present finding of the overall agreement of the observation and estimation on suggests that those multiple kind of phenomena can be discussed by means of the Pride's formation of on the basis of concept that those phenomena are induced by variety of the cracks taking place in the nucleation period. We have already impressive observation of magnetic ULF band anomalies (Han, 2012) occurred simultaneously with the slow slip at deep plate boundary by means of high sensitive seismometer (Ozawa et al., 2003). Many of observational electric anomalies (Hayakawa and Fujinawa, 1994) can be more satisfactory interpreted on the basis of the unified scheme. Multidisciplinary approach on the basis of the unified theory is expected to open new window for practical earthquake prediction methods as well as for geophysical survey. For instance we can investigate the fluid motion associated with fracture in a porous medium as conducted in the laboratory (Haas *et al*., 2013).

Keywords: seismo-electromagnetics, short-term forecasting, micro-crack, porous medium, Electrical properties, Acoustic property

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SCG15-05 Room:203 Time:May 24 16:50-17:05

The Mechanism of the Pre-seismic Changes of the Tidal Deviation of Groundwater Level in Hualien City, Taiwan

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The different response by various natural stimuli and processes (tidal force, barometric loading, ground shaking and crustal strain) were used as the elements of the hydraulic information in the earthquake induced groundwater level changes. Using the ocean tidal force to act as naturally recurring stimuli to provide a sufficiently varied distribution of excitations in time and space, and represented the hydro-geological changes responses to the earthquake processes. The purposes of this study are to analyze the recently observation results of the earthquake induced tidal deviation of groundwater level in observation wells around Hualien city, eastern Taiwan. The analysis of the tidal responses and the atmospheric pressure responses also will be used to estimate the mechanical properties of the aquifer. Comparison the observation between the sea level and the groundwater level changes in the each event, offers the opportunity to discussion the possible mechanism of the hydrologic response to earthquake. Curiously pre-seismic groundwater level changes in the pattern of tidal deviation occurred repeatedly in several local seismic events nearby the Hualien City. Poroelastic model been used to act as the simulation tool to fit to the pre-seismic groundwater level changes. The results shows groundwater preseismic change could be simulated by a recharge or discharge at a fault zone with poroelastic model. The numerical results could support our conceptual model with a permeable fault zone between sea loading and groundwater responses. Our numerical model provides some information for the preseismic mechanism but more investigations are required.

Keywords: Groundwater, Permeability Structure, Pre-seismic

Japan Geoscience Union Meeting 2015
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SCG15-06 Room:203 Time:May 24 17:05-17:25

Seismoelectric Interferometry

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The seismoelectric effect is a very interesting and complex physical phenomenon, dealing with the subsurface coupling between mechanical poroelastic wavefields and electromagnetic diffusive fields. Therefore, the seismoelectric method can provide us with both seismic resolution and electromagnetic sensitivity at the same time. In addition, several studies have shown that the seismoelectric method can provide supplemental information about porosity and permeability, or on pore–fluid properties such as viscosity. These features do not only make seismoelectrics a worthwhile phenomenon to study for exploration purposes, but also for e.g. the field of earthquake mechanisms and risk analysis. Two types of seismoelectric coupling can be distinguished:

1) localized coupling generating an electromagnetic field that is present inside the seismic wave and travels with seismic velocity, the so-called coseismic field.

2) An independently diffusing electromagnetic field with electromagnetic velocity, providing us with information at depth. This is referred to as the seismoelectric conversion (or interface response).

At present, the key challenge for seismoelectrics is its measurability in the field. Due to the very weak signal to noise ratio of especially the second-order seismoelectric conversion, the events are often not detectable. In order to make seismoelectrics applicable in the field, we need to find ways to improve the signal to noise ratio of this second order effect. From seismic interferometry, we know that by cross–correlating recorded fields, virtual source responses can be simulated. In this process, stacking inherently takes place thereby possibly enhancing the signal-to-noise ratio of the records. We here present initial results of applying interferometric principles to seismoelectric phenomena. Can we indeed retrieve the desired seismoelectric virtual source responses that we are after, by cross-correlating selected responses due to boundary sources of a certain type (mechanical or electrical)? We explore the area of seismoelectric interferometry using our analytically based, numerical modeling code ESSEMOD (ElectroSeismic and Seismoelectric Modeling). Acknowledgements: Shell–FOM project, 'Innovative physics for oil and gas'.

Keywords: Seismoelectric, Electroseismic, Interferometry, cross-correlation

Japan Geoscience Union Meeting 2015
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SCG15-07 Room:203 Time:May 24 17:25-17:40

Feasibility study of characterizing crustal cracks by EMR in the VLF band using interferometry

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In this paper we present the three-dimensional (3D) numerical simulation results aimed to shed a light on the feasibility of mapping the density and orientation of crustal cracks by looking into the features of electromagnetic radiation (EMR) from cracks using interferometry from a surface observation array. We use 3D finite difference time domain (FDTD) technique to conduct the numerical modeling. The cracks are statistically generated with specified density, size, orientations, and electromagnetic (EM) properties. The measuring points are placed on the earth surface and can be distributed in any arbitrary fashion to investigate the optimistic configuration of the field observation arrays. The objective of this numerical test is two-fold:

1) Investigate the EMR efficiency on the surface by looking into different physical mechanisms (such as charge separation processes between (OKeefe and Thiel, 1995) or along (Gershenzon et al., 1986) the crack walls associated with micro-cracking; 2) crack-induced movement and reorientation of dislocations (Misra and Gosh, 1980; Slifkin, 1993); 3) the surface vibrational-wave model of Frid et al. (2003) and Rabinovitch et al. (2007)).

2) Investigate the influence of strong radiation from VLF transmitters on using EMR for tectonic and earthquake studies.

As the existing preliminary observations (e.g., Krumbholz, 2010; Krumbholz et al. 2012) have shown, the hope of using EMR to determine the horizontal principal stress orientation at one location by looking into the EM amplitude from a single station alone is diminished. This motivates us to look into the interferometry approach to eliminate the strong influence of active VLF transmissions.

Keywords: seismoelecgtric, crustal cracks, interferometry, VLF, electromagnetic radiation, numerical simulation

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SCG15-P01 Room:Convention Hall Time:May 24 18:15-19:30

Towards Seismoelectric Inversion: Sensitivity Analysis using Resolution Functions

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When a mechanical wavefield propagates through a porous, fluid-filled medium, a complex physical phenomenon called the seismoelectric effect can occur. Due to the presence of an electrical double layer at the microscale, coupling between the mechanical wavefield

and electromagnetic fields can occur. Pride (1994) has developed a set of governing equations that describes the seismoelectric effect using Biot's poroelasticity equations coupled to Maxwell's electromagnetic equations. Coupling effectively takes place at two locations:

1) Inside the seismic wavefield, copropagating with the seismic wave velocity and therefore referred to as the coseismic field. This field provides us with local information in the vicinity of the receivers.

2) At locations where contrasts in medium parameters occur (for example interfaces) an independently diffusing electromagnetic field is generated, referred to as the interface

response field or seismoelectric conversion. The seismoelectric method tries to take advantage of this subsurface coupling as a geophysical tool for exploration or monitoring purposes, as well as for borehole applications. Besides providing us with seismic resolution and electromagnetic fluid–sensitivity at the same time, several studies have also shown that seismoelectric fields can provide us with supplemental information about porosity, permeability and pore-fluid properties such as viscosity. The seismoelectric method can potentially be used for the detection and monitoring of oil/water contacts, several (near–)borehole applications and the monitoring of aquifers.

However, the seismoelectric effect is described by a combination of many (often mutually related) subsurface parameters. Therefore, inversion of seismoelectric data for a specific parameter is costly and solving for such a parameter uniquely might be even impossible. By carrying out sensitivity analyses prior to inversion, we can investigate whether the measured fields are actually sensitive to the parameter(s) of interest. In addition, sensitivity analyses can provide information about the optimal acquisition design or help us investigating time–lapse perturbations. We will start by explaining the theory of resolution functions using a seismoelectric example. We will derive the seismoelectric resolution function for inversion for a bulk density contrast. We will compute this resolution function as the least-squares solution to the normal equation. We will demonstrate the effectiveness of this method by first carrying out a purely electromagnetic sensitivity analysis for a point perturbation in conductivity. These results will be compared with literature results. As a next step, we investigate the electromagnetic sensitivity to point scatterers above and below highly conductive layers. Finally, we will present the results of the fully–coupled seismoelectric sensitivity analysis for a bulk density contrast, using single–frequency multicomponent line data.

Keywords: Seismoelectric, electromagnetic, resolution function, sensitivity analysis

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SCG15-P02 Room:Convention Hall Time:May 24 18:15-19:30

Application Prospects of SKZ-1 4-component borehole strain meter

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High sensitivity borehole strain meter has good dynamic performance, work stability, anti-interference ability in detecting the regional crustal activity. The structure using four sensing elements that were set at intervals of 45 degree can have a simple ”reliability test formula of measurement data” to realize the real-time inspection of data reliability. This method of work has become an important detection means of multi-component borehole strain observation in Mainland China. The structure of the new model introduced by this paper has been confirmed that it can obviously improve the mutual verification result of strain measurement data because the important improvements have been made on displacement transfer structure of underground instrument, and the borehole strain meter has got two pre-seismic anomaly information in experimental observation in ZhaoTong area, YunNan. Now the types of equipment submitted to this conference is expected participants to consider if it can be used in electromagnetic wave observation station network and become an auxiliary observation means that is matching.

The instrument feature are that it uses four sensing elements that were set at intervals of 45 degree and checking formula is simple and clear: U1+U3=U2+U4. Reliability of observation has been obviously improved because four elements are embedded in the 8 narrow ribs. Cross check degree of the data has reached 0.99.

Preliminary results: 1. M5.7 YiLiang earthquake occurred (longitude 104.00, latitude 27.5) at 11:19 on September 7th, 2012. Seven days before the earthquake, obvious strain anomaly of four directions appeared at the same time in YiLiang Seismic Station which epicenter distance is 15.5km. But in DaGuan Seismic Station which epicenter distance is 30km, correlation coefficient of the two surface strain curve is 0.99 or so, there was no significant association with this earthquake. NS and NW data signals of the borehole strain meter appeared low frequency noise 11-17 minutes before the M5.7 DaGuan earthquake, and the earthquake occurred two minutes after the end of noise. In this earthquake, what is difficult to understand is that the low frequency signal curve shape is different between the NS curve and NW curve. Cycle of NS is about 15s and the cycle of NW is about 60s. But NE, EW data curve did not appear similar situation and the relationship between the low frequency data of four components did not conform to checking formula. The cause of this kind of signal is unclear but it may be a extremely important clue. We suspect that it may be connected with the underground electromagnetic signal because it doesn’t conform to checking formula. 2. The LuDian M6.5 earthquake occurred on August 3, 2014, epicenter was located 26km southwest of LuDian Seismic Station. Except that strain data appeared changes 3 days before the earthquake, the correlation coefficient of surface strain have different values in different stages of earthquake.

Keywords: Borehole strain, Observation technology, Pre-seismic anomaly information

Date	July 17th –July 31th	August 1st –August 3rd	August 3rd –September 15th	September 15th –September 29th
Correlation coefficients	0.981	0.880	0.501	0.998
Introduction	no abnormal	abnormal pre-earthquake	post-quake adjustment	post-quake stability