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

STT13-P01 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

地表磁場成分を用いた電磁マイグレーションによる地下構造可視化の研究
Subsurface imaging with EM migration of magnetic fields

兵藤 大祐 [1] ; 後藤 忠徳 [1] ; 三ケ田 均 [1] ; 武川 順一 [1*]
HYODO, Daisuke[1] ; GOTO, Tada-nori[1] ; MIKADA, Hitoshi[1] ; TAKEKAWA, Junichi[1*]

[1] 京都大学大学院工学研究科
[1]Graduate school of Engineering, Kyoto University

The underground impedance data is estimated by observing and analyzing both electric and magnetic components in the magnetotelluric (MT) method. Although this method is often used in fault surveys or geothermal prospecting, it has the two problems caused by the observation of electric components. One is that the static shift effect bias the apparent resistivity at the surface, and the other is that it is difficult to secure broad places for the observation of electric fields. Furthermore the analysis of electromagnetic data is also challenging because of its high computational costs, especially in three-dimensional cases. This causes barriers to application to large amounts of field data. So, a new technology which can estimate the subsurface information simpler and faster is needed.

In this study, we suggest the new method to use magnetic components at the surface in order to overcome these problems. The static shift effect can be controlled and the great mobility of magnetometers makes it possible to obtain data at a lot of sites, if magnetic fields are used as analysis data. Magnetic components are applied to not inversion method but migration method, which is generally the visualization method in seismic data processing to save computational cost. We adopted the PSPI (Phase-Shift Plus Interpolation) method (Gazdag and Sguazzero, 1984) and applied this method to the magnetic fields at the surface. In the case of applying the migration technique to the electromagnetic data, it is very important to select the correct frequency band to prevent the multiple reflection and attenuation of the electromagnetic waves.

Through the numerical calculation analyses and the analysis of field data, it was confirmed that applying migration method to magnetic components is the effective. In this migration method, the large value of reflection intensity is estimated around the area if the proper resistivity structure is assigned to the migration. This means that the resistivity structures in the subsurface have an effect on the migration results. In the analysis of the real field data around an active fault, large reflection intensity was estimated beneath the active fault. We discussed the results of the estimated apparent resistivity cross section and the migration results with the geological structure of the area and a previous 2D MT inversion result.

In conclusion, our method can estimate the underground resistivity structure simpler and faster. The combination of this electromagnetic migration method and inversion has possibility to reveal more detailed subsurface resistivity structure.

Keywords: electromagnetic migration, magnetic fields

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STT13-P02 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

Pareto-optimal Joint Inversion Modelling and Data Set Compatibility Analysis
Pareto-optimal Joint Inversion Modelling and Data Set Compatibility Analysis

SCHNAIDT, Sebastian[1] ; KRIEGER, Lars[1*] ; HEINSON, Graham[1]
SCHNAIDT, Sebastian[1] ; KRIEGER, Lars[1*] ; HEINSON, Graham[1]

[1]Department of Earth Sciences, School of Physical Sciences, University of Adelaide, Adelaide (AUS)
[1]Department of Earth Sciences, School of Physical Sciences, University of Adelaide, Adelaide (AUS)

In the process of modelling geophysical properties, jointly inverting different data sets can greatly improve the results. In order to conduct a joint inversion modelling, a relationship between the different data sets has to be established, which can be either be of analytical or structural nature. Classically, the joint inversion problem is then expressed as a scalar objective function, which combines the misfit functions of all involved data sets combined with a joint term accounting for the assumed connection between the data sets. This method bears two major disadvantages. Firstly, a weighting of the data sets is enforced by aggregating all misfit terms. Secondly, the data sets cannot be assessed with respect to their compatibility. Data sets are compatible if they are sensitive to similar physical features, and the joint interpretation of incompatible data sets can lead to incorrect resulting models.

In order to generate unbiased joint inversion models, it is important to mitigate the influence of weighting and to analyse the compatibility of data sets. Therefore, we have developed a new approach to the joint inversion modelling of geophysical data. We present *MOJO*, a Pareto-optimal multi-objective joint inversion algorithm. It is based on an advanced genetic algorithm, hence it does not only calculate a single optimised model, but a distribution of possible models as final result. In contrast to common approaches, *MOJO* treats data sets as a separate objectives, which avoids spurious weighting. Additionally, we use the output of *MOJO* to calculate and evaluate curves of the trade-off between the different objectives. The shapes and evolutions of these curves yield a measure for the compatibility of the used data sets. Furthermore, the evaluation of the resulting model distribution provides valuable uncertainty estimates.

キーワード: Multi-objective optimisation, Joint-inversion, Data set compatibility, Model uncertainty, Magnetotellurics
Keywords: Multi-objective optimisation, Joint-inversion, Data set compatibility, Model uncertainty, Magnetotellurics

Japan Geoscience Union Meeting 2015
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STT13-P03 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

Interferometric location of microseismic events induced by gas storage operations
Interferometric location of microseismic events induced by gas storage operations

GRIGOLI, Francesco[1*] ; CESCA, Simone[2]
GRIGOLI, Francesco[1*] ; CESCA, Simone[2]

[1]Institute of Earth and Environmental Sciences, University of Potsdam, Germany, [2]GFZ German Research Centre for Geoscience, Section 2.1 Earthquake and Volcano physics, Germany
[1]Institute of Earth and Environmental Sciences, University of Potsdam, Germany, [2]GFZ German Research Centre for Geoscience, Section 2.1 Earthquake and Volcano physics, Germany

Underground gas storage is a common industrial operation that consist in the injection of natural gas in aquifers, underground cavities or depleted hydrocarbon reservoirs. Gas is seasonally injected or extracted to meet the market demand. Although these operations rarely stimulated seismicity, a recent case at the Castor platform in the offshore Spain was accompanied by a significant seismic sequence, culminated with a magnitude Mw 4.3 earthquake (Cesca et al. 2014). Ad hoc microseismic monitoring networks are nowadays extensively used to analyse the induced microseismicity generated by these industrial operations. However, in many cases, the lack of local microseismic monitoring networks limits the performance of the standard data analysis procedures. In such cases, non conventional methods need to be established. Within this context, we extend here the analysis of triggered seismicity related to gas injection at the Castor platform, in September-October 2013, where standard location procedures failed for magnitudes below Ml 2. In this work we relocate these low magnitude events using an interferometry based location method (Snieder and Vrijlandt, 2005). This technique exploits slight changes in the coda waves between two seismic events within a cluster. We proof that microseismic events can be classified in different families by combining a waveform correlation analysis and a clustering technique. Clustered events are characterized by a high similarity of waveforms, which implies a similarity in both source mechanism and location. In these conditions, the analysis of seismic coda recorded at a single receiver can be used to infer a measure of the spatial separation between two seismic sources. Coda waves are radiated in all directions with a radiation pattern determined by the source mechanism and a small change in the source position affects the interference pattern of the scattered waves that constitute the coda. This change in the coda waves is used to constrain the interevent distance for each events pair. Absolute locations can be then retrieved by considering all interevent distances, a procedure which requires at least three reference locations. We discuss the potential of the coda interferometry location approach to monitor triggered and induced seismicity, by relocating about 1000 seismic events of the September-October 2013 seismic sequence offshore Spain, close to the Castor project injection platform. Results are used to discuss the possible proposed faults scenarios.

References:
Cesca, S. et al. 2014, The 2013 September?October seismic sequence offshore Spain: a case of seismicity triggered by gas injection?, Geophys, Jour. Int., doi: 10.1093/gji/ggu172
Snieder, R., and Vrijlandt, M., 2005. Constraining the source separation with coda wave interferometry: Theory and application to earthquake doublets in the Hayward fault, California, J. Geophys. Res., doi:10.1029/2004JB003317

キーワード: Induced seismicity, Microseismic monitoring, Seismic event location, Seismic interferometry
Keywords: Induced seismicity, Microseismic monitoring, Seismic event location, Seismic interferometry

Japan Geoscience Union Meeting 2015
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STT13-P04 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

Retrieving Focal Mechanism using Double Couple - Tensile Constrained Inversion : Method and Synthetic Tests
Retrieving Focal Mechanism using Double Couple - Tensile Constrained Inversion : Method and Synthetic Tests

飯田 周平 [1*] ; 金 亜伊 [1]
IIDA, Shuhei[1*] ; KIM, Ahyi[1]

[1] 横浜市立大学
[1]Yokohama City University

Understanding the source characteristics of hydraulic fracturing induced microearthquakes is expected to provide better understanding of both the fracturing process and the influence of pre-existing structures on the distribution of events. However, details of the source characteristics of the microearthquakes remain largely unknown. One controversial issue is whether a significant volumetric change occurs because of the stimulation. Answering this question is important to provide the insight of the future effective and safer hydraulic fracturing. Although the moment tensor inversion is one of the best approaches for studying source mechanisms, it is often biased due to uncertainty of geologic model, sparse receiver coverage and low signal to noise ratio for this types of induced earthquake analyses. So it is necessary to quantify the factors which bias the solution. Herein, to address this question, we modified the double couple focal mechanism inversion method using the body-wave amplitude ratio and polarities developed by Snoke (2003) for stimulation induced microearthquake analysis. Since our goal is to figure out whether it is possible to identify volumetric change with limited receiver azimuthal coverage, it is necessary to incorporate the non-double couple mechanism in the inversion. Since the mechanism of the microearthquakes can be considered as 1) shear slip along the pre-existing fracture surface, 2) an tensile displacement which increase the porosity, or 3) a combination of these mechanisms, we added tensile crack component to the original method. In this manner, we have smaller degree of freedom to stabilize the inversion than that of full moment tensor case. In this study we will examine the performance of the method with synthetic tests under various conditions.

キーワード: 誘発地震, 水圧破砕, 震源メカニズム, テンサイルクラック
Keywords: induced seismicity, hydraulic fracturing, focal mechanism, tensile crack

Japan Geoscience Union Meeting 2015
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STT13-P05 会場:コンベンションホール 時間:5 月 27 日 18:15-19:30

Extraction of body waves from seismic ambient noise
Extraction of body waves from seismic ambient noise

Kim Eun Mi[1*] ; KANG Tae seob[1] ; KIM Tae sung[2] ; KIM Min wook[1]
KIM, Eun mi[1*] ; KANG, Tae seob[1] ; KIM, Tae sung[2] ; KIM, Min wook[1]

[1]Pukyong National University, [2]Korea Institute of Geoscience and Mineral Resources
[1]Pukyong National University, [2]Korea Institute of Geoscience and Mineral Resources

Ambient noise cross-correlation is used in seismology to obtain the part of the surface waves and applied to the theoretical researches and various experiments. Obtaining the part of body waves from the ambient noise correlation is difficult to recognize because of the feature decreasing body waves along the travel path. However, the travel times of body waves detected from temporal and spacial events occurrence involve uncertainty of the epicenter and accompany temporal-spacial restriction. On the other hand, ambient noise is always occurred and is obtained at the all stations. So it can be applied to research of the internal earth when the case of extracting the body waves using the cross-correlation is possible. This study shows that body waves can be observed by analyzing the ambient noise recorded seismic data in South Korea. Using 42 broad-band three components stations located on the South Korea. The data removed the mean and trend are filtered high-frequency band(0.5-2Hz). The noise correlations were calculated for all combinations of radial, transverse and veltical components, which required rotation of the horizontal components for each station pair according to the azimuth at each station of the greatcircle between the two stations. Removing the part of broad-band signals effected by occurring event, the part of standard deviations more than three times are removed. And it applied spectral whitening to reduce effects of the surface waves. After data processing, all ambient noise signals are cross-correlated and temporal stacked. We found the signals propagating from one station to another station, this signals can be interpreted as the body waves distinguished surface travel-time in high-frequency band. From this analysis, we can extract the body waves using ambient noise cross correlation of continuous data at the stations.

キーワード: ambient noise, cross correlation
Keywords: ambient noise, cross correlation