[EE] Evening Poster | S (Solid Earth Sciences) | S-SS Seismology

[S-SS03]Induced and triggered seismicity: case-studies, monitoring and modeling techniques

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Induced and triggered seismicity occurs in conjunction with human activities such as reservoir impoundments, mining operations, conventional and non-conventional hydrocarbon production, geothermal energy exploitation, wastewater disposal, CO2 sequestration and gas storage operations as well as volcanic and hydrogeological processes. The stability of faults is affected by external solicitations such as pore-pressure diffusion, relaxation effects and stress field perturbations related to mass and/or volume changes, dike intrusions and earthquake-earthquake interactions. A better understanding of the physical processes governing induced and triggered seismicity is thus important for assessing the risk of current and future industrial activities, including the geological disposal of nuclear waste.

The study of induced and triggered seismicity is inherently an interdisciplinary problem, which requires the combination of seismological, hydrogeological and geodetic data as well as a wide range of modeling approaches. This session covers the analysis and modeling of induced and triggered seismicity at different spatial scales and in different environments. We welcome contributions from earthquake and volcano seismology and geomechanics.

Relevant topics to be presented include - but are not limited to - new methods for microseismicity characterization (both natural and anthropogenic), spatio-temporal variations of physical parameters (including stress, pressure and temperature changes), spatio-temporal patterns of seismicity, modeling strategies and case-studies.

The goal of the session is to cover both observational, theoretical and experimental aspects on the topics summarized above.

[SSS03-P01]Estimation of moment magnitude of acoustic emissions induced by hydraulic fracturing in the laboratory

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In shale gas/oil development, the permeability of reservoir rocks is increased by hydraulic fracturing to extract those resources. Because the influence region of such fracturing is often estimated by microseismic activities, better understanding of the relation between seismic activities and the induced fractures is desired. For this purpose, we have conducted hydraulic fracturing experiments in the laboratory by using a thermosetting acrylic resin mixed with a fluorescent compound as the fracturing fluid with monitoring acoustic emissions (AEs). These experiments allowed us to observe fluid

penetration regions in resolution of several tens of micrometers on cross-sectional planes cut after the fracturing.

To discuss the relation between the observed fractures and AEs, the source size of AEs should be compared the fracture structure revealed by the fluorescent method. However, the estimation of absolute magnitudes of AEs observed in the laboratory is difficult because AE sensors have complicated frequency responses that depends on coupling condition with specimen, so many previous studies used only relative magnitudes estimated from waveform amplitudes. In the present study, we evaluate frequency characteristics and absolute sensitivity of AE sensors by using lesser Doppler velocity meter, which has completely flat frequency response, and estimated moment magnitudes (Mw) for individual AEs from their amplitude spectra. We also estimated the source sizes assuming a circular crack model from the obtained Mw, allowing us to compare the observed fractures by the fluorescent method.

In our experiments, we used samples obtained from an exposure of Eagle ford formation, where actual shale gas/oil development have been conducted. We used three blocks with dimensions of 65 x 65 x 130 mm that have a wellbore of 6 mm in diameter. The fluorescent resin (methyl methacrylate; a viscosity of 0.80 mPa・s at room temperature) is injected to the wellbore through a packer to induce hydraulic fracturing. AEs were monitored by 24 AE sensors set onto the surface of the samples and their waveforms were recorded with sampling rate of 10 MS/s continuously. We cutout AE waveforms from the data and applying an automatic algorithm to measure P-wave arrival times and located their hypocenters. We then applied cross-correlation travel time reading technique and the double difference method for the AEs to obtain more accurate hypocenters. For all the three experiments, 415–466 hypocenters were obtained. They exhibited thin, sharp two-dimensional distribution with 1 mm or less in thickness that likely delineate the induced fractures. The fractures on sliced samples observed after the experiments correspond to the AE distribution very well.

The frequency characteristics of the sensors was estimated in the following procedure. Firstly, we set a transducer on an aluminum block to generate pulse, and observed waveform by LDV at the opposite site. We observed oscillation at the same point by AE sensors and deconvolved the signals by the LDV record to obtain the frequency characteristics of the sensor. Because the characteristics depends on the coupling condition between the sensor and the sample, we repeat this test 16 times by reattaching the AE sensor and the averaged result was used in the following analysis. We did not replace the transducer to keep the characterizes throughout the test.

We corrected amplitude spectra of the AE events during the fracturing by using the frequency response obtained by the above procedure. After applying additional correction for the sensor directivity, we obtained amplitude spectra of the actual ground motion. Based on the spectra, we estimated seismic moment Mo and Mw for individual AEs by assuming ω^2-model, and obtained Mw between -8.5 and -7.5, corresponding cracks of 0.3–1 mm in size if assuming stress drop of 3 MPa. The size distribution were obeyed Gutenberg Richter law and b-values of 1.3 was obtained.