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Editorial: Geomechanics and induced seismicity for underground energy and resources exploitation

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Editorial on the Research Topic
Geomechanics and induced seismicity for underground energy and resources exploitation

1 Introduction

Exploiting energy and resources from the Earth subsurface is a development trend all over the world. These anthropogenic activities lead to underground stress perturbations, which may trigger hazardous events. Deep mining and tunneling may induce dynamic disasters such as fault slippage and rock burst, leading to serious casualties and economic losses. Engineering applications such as well drilling, fluid injection into the subsurface, and the creation of deep underground space provide direct sources to seismic activities. It is imperative to minimize the risk of these disasters and even prevent their occurrences, which is crucial for a safe and efficient energy and resources exploitation. However, the physical mechanism of induced hazardous events is not well understood. Through innovative theoretical analysis and techniques (Ma et al., 2018; Ma et al., 2019a; Ma et al., 2019b; Ma et al., 2019; Dong et al., 2022a; Dong and Luo, 2022; Li et al.; Meng et al.; Sun et al., 2022), experimental techniques (Dong et al., 2021a; Dong et al.; Chen et al.; Dong et al. 2020a; Hermans et al. 2018; Dong et al. 2022b; Dong et al., 2023), data mining (Dong et al., 2022c; Qian et al.; Yu et al.), and simulation methods (Dong and Luo, 2020; Cao et al., 2020; Dong et al. 2021b; Lei; Xu et al.), researchers conducted in-depth research on these key problems. Efforts in integrating these technological means will help advance geomechanics and induced seismicity-related research that contributes to resolving challenging Research Topic in the exploitation of underground energy and resources. This Research Topic aims to focus on the most recent theoretical, experimental, and technological advances in Geomechanics and Induced Seismicity for Underground Energy and Resources Exploitation. This editorial presents a brief summary of the articles published under this Research Topic.

2 Theoretical analysis and techniques

Meng et al. presented a non-parametric simultaneous reconstruction and denoising of seismic data *via* sparse and low-rank regularization, efficiently and automatically dealing with the prestack gathers. The effectiveness of this method is verified through practical applications. Beside the hypothesis that the seismic signal is compressible, the proposed method makes no additional prior assumptions on the original data. First, the solution matrix is extracted from the Fourier dictionary. Then the reconstruction and denoising are performed successively in the sparse domain. The key parameters are estimated in a data-driven framework. The method can reduce the computational complexity of sparse representation. It can be effectively applied to data reconstruction and denoising.

Li et al. established a tunnel excavation model test based on a true triaxial stress loading system, combined with three-dimensional scanning technology for a superimposed sandy soil. Based on this model, the vector displacement response range and three-dimensional deformation characteristics of the excavation face were studied in the main displacement affected area around the excavation face. Meanwhile, the deformation characteristics, such as vertical settlement and horizontal displacement of the stratum in the main influence affected area were analyzed. The results show that the model can provide some references for the excavation engineering of superimposed sand-soil tunnels.

3 Progress in experimental research

Chen et al. studied the deterioration characteristics of the tunnel surrounding rock under the scouring of flowing groundwater. Experiments were carried out with acidic solutions representative of the groundwater composition. The microstructure of granite samples cored on site, deformation features, and evolution characteristics of mechanical parameters under saturations with different flow rates and various pH values were analyzed using scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), nuclear magnetic resonance (NMR), and X-ray diffraction (XRD). The experimental results can bring inspiration to the research in this field.

Dong et al. proposed a comprehensive abnormal area detection method, which is based on transient electromagnetic detection and supplemented *via* drilling detection. It was used to determine the spatial position and location of heterogeneous rock mass in the goaf underlying the subway station. The detection results provide a basis for the safety and stability of the proposed substation foundation. This method provides a reference for the detection of the stability of non-homogeneous rock masses in the extraction area, and helps to take effective management measures for heterogeneous rock masses.

4 Data mining and simulation methods

Yu et al. proposed a method for simultaneously imaging multi-fracture networks using microseismic monitoring data. The algorithms commonly used in multi-model fitting were integrated to produce an upgraded method that accommodates geophysical data for faster and more accurate simultaneous multi-fracture model imaging within a point cloud. The accuracy of the method was improved using circular calculation and density-based spatial clustering of applications with noise, such that the estimated fracture orientations correspond well to those at the actual locations. The proposed algorithm was applied to synthetic data to assess the impact of considering orientation and outlier data on the model results. Field microseismic data were also used to depict fractures representing the dominant orientation, and the errors of the strike and dip angle estimates were 2.89% and 2.83%, respectively. Results demonstrate the suitability of the algorithm for fast and accurate field data modeling.

Qian et al. observed paired signals that are induced by cavern roof instability for the first time with the aid of a microseismic monitoring system. By studying the two events of the paired signals, the whole process of rock debris rupture development at the cave roof, the time of rock debris crossing the brine and the collision process of rock debris at the cave floor were analyzed. It was found that by locating the first event of the paired signals, the spatial distribution of the roof can be outlined. Using the delay time between the two events of the paired signals, the height of the cave chamber can be estimated qualitatively. By observing the collision signal, the size of the rock debris can be further analyzed. The derived information could be combined to assess the cavern collapse hazard through some rock mechanics analysis.

Xu et al. analyzed the equivalent elastic modulus and occurrence effect of rockmass with orthogonal random joints. Firstly, the eigenvalue distribution function of joints is obtained through statistically analyzing a large number of joints in the field. Secondly, the orthogonal random joint model is constructed using Monte Carlo method based on UDEC software platform. Then, a large number of numerical experiments of discrete elements are carried out. The results showed that the equivalent elastic modulus of rockmass with orthogonal random joints has an obvious scale effect. The relationship between the average equivalent elastic modulus and the representative basic volume (REV) size of rockmass follows a negative power function distribution. Under different joint angles, the standard deviation and variation coefficient of the equivalent elastic modulus of rockmass are distributed discretely. When the model size reaches REV size, the occurrence effect of equivalent elastic modulus of rockmass is not significant.

Lei analyzed the relationship between the 2018 Hokkaido East Ibri earthquake and carbon dioxide (CO_2) injection through a geomechanical model. The results show that even under extreme conditions, CO_2 is injected at the rate of 180,000 tons/year for 10 consecutive years, the impact of CO_2 injection on the Yibuli seismic fault is far lower than that caused by the Earth tide. There is no convincing mechanism to allow fluid channels to heal and block the natural fluid flow along the fault in a short time. CO_2 injection is therefore unlikely to be a trigger for the East Ibri earthquake. The geological storage of CO_2 is very important for slowing down the trend of global warming. For fault reactivation and earthquake caused by risk related injection, it is necessary to avoid too large and too small assessment.

5 Conclusion

The study of geomechanics and induced earthquake of underground energy and resource development is of great significance to study, understand and predict subsurface systems affected by the exploitation of natural resources. In particular, the prediction of disasters caused by human activities is still a very important research topic. We sincerely thank all the authors for their outstanding and meaningful contributions to this Research Topic. It is hoped that there will be more relevant research in the field of geomechanics and geophysics in the future to bring further breakthroughs in theory, field observation, laboratory experiments, numerical simulation, and the development of geophysical monitoring equipment and technology towards a safe underground energy and resources exploitation.

Author contributions

LD and WC drafted the first version of the editorial. LD, WC, and TH revised the first draft and made contributions about papers they edited.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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