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Editorial: Instability mechanisms and disaster prevention of coal and rock in deep underground space

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Editorial on the Research Topic
Instability mechanisms and disaster prevention of coal and rock in deep underground space

Introduction

Consistent exploitation of natural resources is depleting shallow mineral reserves, making it increasingly important to explore and utilize deeper mineral resources. However, as the exploitation depth increases, so too does the complexity and variability of the stress environment, solid-fluid interactions, and pore and fracture networks of underground coal and rock structures. This leads to an increase in the number of associated disasters. The focus of the Research Topic is to understand the instability mechanisms and develop disaster prevention measures for coal and rock structures in deep underground spaces. It is crucial to effectively prevent and control coal and rock disasters and more efforts should be made to research the relevant properties of coal and rock. This Research Topic includes 11 papers that primarily discuss the instability mechanisms of coal and rock, dynamic disaster prevention, coal and rock experiments, and their fluid flow characteristics.

The application of neural network technology in natural gas production and storage

Neural network technology has been applied to gas production and storage to meet the increasing pressure of natural gas demand, energy consumption control, and environmental protection. The development and utilization of natural gas reserves in the underground space have been discussed by Zhang K. et al. in their work "*Cluster analysis of carboniferous gas reservoirs and application of a recovery prediction model.*" The authors used the Pearson correlation coefficient and the neural network weight calculation methods to analyze and calculate the static indicators of carboniferous gas reservoirs. They established recovery rate prediction models for various types of gas reservoirs using the BP neural network, and the accuracy of the model was verified using examples. To address the current research problems on natural gas reserves, such as the lack of comparative analysis of multiple neural network architectures and a comprehensive evaluation of research, Zhan et al. utilized cluster analysis and the analytic hierarchy process (AHP) to determine the influencing factors of gas reserves. The researchers employed the backpropagation algorithm to construct, train, and optimize a neural network model based on a multi-layer perceptron (MLP) to improve the stability of natural gas reserve enhancement prediction. The predictive combination model helps to accurately forecast the trend of natural gas production and formulate development plans. Li H. et al. combined the Hubbert model, Gauss model, and GM (1, N) model for prediction. They used Shapley values to allocate weights to the three models to reduce errors caused by the shortcomings of individual models.

Rock mechanical properties and degradation mechanisms

The study of the physical and mechanical properties of rock and how it deforms under different conditions is important for the prevention of coal and rock disasters. Li et al. conducted tests on three groups of samples subjected to simulated seismic stress loads to analyze the degradation mechanism of the physical and mechanical properties of phosphate ore under saturation. The authors conducted fatigue load and conventional triaxial compression tests and analyzed physical and degradation characteristics, strength, and failure characteristics. In their own study of the degradation mechanisms of the mechanical properties of phosphorite under different saturation periods, Li et al. conducted tests using an ultrasonic detection device and conventional triaxial compression experiments. Additionally, neural network modeling was used to analyze the experimental and mechanical parameters; the average accuracy of the model was 0.89. The model demonstrates the mechanical properties of the sample under water-saturation and ambient pressure. In further research on the deep mining working face, Lu et al. combined theoretical calculations, numerical simulations, and field tests to determine the height of the "three vertical zones" of overburden strata. They optimized the design parameters of the high-level drilling to improve the gas drainage effect.

Geological hazard detection and protection

Unmanned aerial vehicles (UAVs) are now being used to detect and protect against geological hazards. In the article titled "*Mapping mining-induced ground fissures and their evolution using UAV photogrammetry*" Fu et al. introduced a method for identifying ground fissures using UAV remote sensing imagery. This involves combining geometric morphology and optical features to extract ground fissures. To ensure accuracy, multiple algorithms were compared for the ground fissure extraction method, and the study also analyzed the impact of UAV image capture at different flight heights. The accuracy of the method was quantitatively evaluated using the Receiver Operating Characteristic (ROC) Curve.

Application of numerical mathematical models and numerical simulations in rock engineering

The drilling process has been revolutionized by the development of mathematical models that paved the way for digital drilling technology. This has provided new possibilities for the real-time determination of rock strength parameters. In the research "*A new method for determining strength parameters of rock using digital drilling technology*" by Qiang et al., the XCY-1 rock mechanical parameter drilling system was used to conduct digital drilling tests. Through the mechanical balance of the drill, an analytical model was established and a method for predicting the rock friction angle was proposed based on the relationship between the parameters. Moreover, a new method for determining rock strength was introduced, which relies on the rock cutting strength ratio and two strength fitting formulas. The predicted values were close to the actual values, which improved the efficiency of rock strength testing.

Numerical simulation is widely used in tunnel engineering. Ma et al. used COMSOL Multiphysics, a multi-physics fluid calculation software, to simulate and calculate the distribution of the first, second, and third-level return airfields for ventilation in the working area over the tunnel. Zhang X. et al. established a three-dimensional model of the jet ventilation tunnel and precisely divided the mesh using ICEM-CFD software to study the distribution characteristics of harmful gases such as methane and hydrogen sulfide in the tunnel. Xue et al. conducted numerical simulations on triaxial compression tests of sandy soil to analyze its microscopic mechanical properties. They also established a simulated excavation calculation model for sandy rock formations using FLAC3D finite difference software and introduced the safety factor K as a stability evaluation index to analyze the surface stability of the sandstone tunnel.

In summary, numerical simulation and modeling techniques, neural network technology, mathematical model establishment, and UAV remote sensing technology have been applied to study coal and rock instability mechanisms and disaster prevention in deep underground spaces. Coal and rock disasters involve various aspects such as natural gas extraction and storage, rock degradation mechanisms, and tunnel engineering applications. The combination of research on deep underground coal and rock and numerical simulation and modeling techniques will lead to more widespread applications, further optimize the efficiency and accuracy of coal and rock studies, and positively impact production and mining, disaster prevention and control, and coal and rock experiments.

Author contributions

YL: Writing–original draft. YZ: Writing–review and editing. CZ: Writing–review and editing. RF: Writing–review and editing.

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