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Editorial: Evaluation, projection, and prevention of dynamic geological disasters: advances and applications of geophysical methods and numerical modeling

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Editorial on the Research Topic
Evaluation, projection, and prevention of dynamic geological disasters: advances and applications of geophysical methods and numerical modeling

Introduction

The accurate assessment of subsurface geological conditions is imperative for the sustainable management of underground energy resources. As energy exploration extends to greater depths due to depleted shallow reserves, the complexity of geological deformations increases. Integrating various geophysical, geotechnical, and geological investigations with analytical and numerical models has been pursued to address these challenges, yet comprehending deformation mechanisms remains daunting due to subsurface heterogeneities, rheological property changes, and intricate stress states. While significant progress has been made in measurement technologies and advanced modeling, a critical need persists to bridge data and precise geological models, thereby enhancing the quantification of deformations linked to subsurface excavation and resource extraction. This integrated approach is essential for managing uncertain geological conditions that carry considerable societal risks (Khan et al., 2021; Khan et al., 2022). Despite deploying geophysical technologies for the monitoring and early warning of dynamic geological disasters (DGDs), the precise identification and categorization of disaster risks remain challenging due to limitations in information identification, data mining, and processing. Effective prevention and control of DGDs necessitate rapid dynamic monitoring, multi-dimensional intelligent analysis, and comprehensive early-warning strategies. To this end, the objective of this Research Topic is to showcase the latest advancements in evaluating, projecting, and preventing DGDs through innovative geophysical workflows, intelligent approaches, and numerical modeling techniques. Exploring innovative theories, methodologies, and techniques to understand mechanisms, establish early warning systems, and mitigate risks associated with geological disasters in deep engineering is essential to enhance construction safety in these intricate projects. All the submissions within this Research Topic focused on the research domains outlined above.

Rock mechanical properties and deformation behavior

Understanding rock mechanical properties would provide better guidance on deformation mechanisms on the engineering scale, for example, underground space exploration in a complex geological setting (Khan et al., 2023). In an article presented by (Khan M et al.), petrography and joint analysis procedures were performed to assist the analysis of the mechanical properties of the Besham Complex in Northern Pakistan; the authors sought to assess the stability of a tunnel site in the deformed rocks by studying the joint density, mineral composition, micro-cracks, and grain boundaries. They found that the microscopic scale deformation properties were altered in grains and fractures, indicating the joint volume properties in the values of poor rock quality as <25%, followed by the ranges of 25% and 50% for poor-quality rocks and non-friendly to further excavation, respectively Satellite-based analyses can further aid in the development of mapping large-scale regions to determine the zonation of such hazards (Shah et al., 2018; Shah et al., 2019).

Engineering failures in urban infrastructure and dynamic disasters

Satellite data have been used to assist the mitigation of land surface deformation around the world, specifically in the study of the 21 July 2020 landslide in China, where a novel variation in the deformation of −51.6–54.2 mm/year was found for the first time (Khan R et al.). Further study on land deformation hazards revealed that the natural environment and resources in Enshi Prefecture were severely disturbed and posed a threat to the livelihood of the local community. The authors also suggested the inclusion of more satellite clusters for studying such hazards to assist in the development of a forecasting system, such as in previous reports (Shah et al., 2020).

Seismicity of active geological faults

As demonstrated from space-borne Sentinel-1A SAR interferometry, the structure deformation hazard in the Kalabagh strike–slip fault of Pakistan showed a creeping rate of approximately ~4.2 ± 1.3 and 4.8 ± 1.6 mm/year in fault's southern and northern regions, respectively, for 7 consecutive years, with no creeping in the central part (Zafa et al.). Further investigation also confirmed extensive deformation along the northern and southern parts of the faulting region in this 7-year analysis as a consequence of significant tectonic stress accumulation and internal deformation due to the presence of a thick salt layer beneath the Earth's surface. These studies also supported previous reports employing high-resolution satellite images to remotely study real-time deformation in order to warn inhabitants early to mitigate damage to lives (Shah, 2022).

Developmental trends in induced seismic response projecting underground engineering disasters

The prediction and prevention of dynamic geological disasters in underground engineering excavation projects constitute a prominent subject of interest for global academic scholars and industry professionals. The evolutionary mechanism, early warning, and risk mitigation of these disasters vary in shallow and deep engineering due to drastic changes in rock mechanical properties and burial depth. There are various geological disasters across the scale; the types mainly known in underground engineering include rockburst, coal–gas outburst, water intrusion, collapse, and land subsidence. The authors of this editorial are mainly engaged in research on early warning, deformation mechanism, prediction, and prevention of dynamic disasters in deep underground engineering and have made considerable contributions to the advancement in theories, techniques, and related technologies.

The future trajectory of technologies in the realm of "Evaluation, Projection, and Prevention of Dynamic Geological Disasters" is poised for significant advancements driven by the convergence of geophysical methods and numerical modeling. Anticipated developments include the integration of real-time monitoring systems with advanced data analytics, thus enabling more accurate and timely disaster projections. One prominent trend involves the utilization of coupled multi-physics models, integrating various geological, geomechanical, and hydrological factors to provide a more holistic understanding of disaster mechanisms. Furthermore, advancements in high-performance computing are likely to enable finer spatial and temporal resolutions in simulations, enhancing the accuracy of disaster predictions. Incorporating machine learning algorithms into numerical models is also expected to become more prevalent, facilitating real-time data assimilation and adaptive modeling to capture evolving geological dynamics. Lastly, the integration of uncertainty quantification techniques will provide a more comprehensive assessment of model reliability, further refining risk assessment and prevention strategies.

The articles presented herein are poised to provide readers with a comprehensive perspective on recent scientific and technological advancements and pertinent research undertakings. These collective developments are strategically aligned with the overarching aims of accurately forecasting, proactively mitigating, and effectively preventing geological disasters across various contexts.

Author contributions

MK: Conceptualization, Formal Analysis, Resources, Supervision, Writing–original draft. DS: Project administration, Supervision, Validation, Writing–review and editing. MS: Investigation, Methodology, Visualization, Writing–review and editing. ZL: Conceptualization, Resources, Supervision, Writing–review and editing.

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Conflict of interest

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