frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 11 September 2023
DOI 10.3389/feart.2023.1284106

Editorial: Advances and applications of passive seismic source characterization

Lei Li[1,2,3]* and František Staněk[4†]

[1]Key Laboratory of Metallogenic Prediction of Nonferrous Metals and Geological Environment Monitoring (Central South University), Ministry of Education, Changsha, China, [2]Hunan Key Laboratory of Nonferrous Resources and Geological Hazard Exploration, Changsha, China, [3]School of Geosciences and Info-Physics, Central South University, Changsha, China, [4]Colorado School of Mines, Golden, CO, United States

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
Jeroen Van Hunen,
Durham University, United Kingdom

*CORRESPONDENCE
Lei Li,
leileely@126.com

†PRESENT ADDRESS
František Staněk,
Silixa Ltd., Elstree, United Kingdom

RECEIVED 27 August 2023
ACCEPTED 04 September 2023
PUBLISHED 11 September 2023

CITATION
Li L and Staněk F (2023), Editorial: Advances and applications of passive seismic source characterization.
Front. Earth Sci. 11:1284106.
doi: 10.3389/feart.2023.1284106

KEYWORDS

passive seismic, source characterization, microseismic monitoring, induced seismicity, seismic imaging

Editorial on the Research Topic
Advances and applications of passive seismic source characterization

Introduction

Source characterization is a fundamental task of passive seismic monitoring. Spatial-temporal evolution of both, point sources and finite-fault source, provides essential information for timely seismic hazard assessment and advanced analysis of the seismicity in the monitored areas. During the past few decades, the rise of dense seismic arrays and development of advanced array-based techniques lead to studies using recorded wavefields in great detail. Moreover, emerging technologies like distributed acoustic sensing (DAS) and machine learning also show great potential in advancing passive seismic imaging and source characterization. Besides, non-earthquake sources and ambient noise are also contributing to infrastructure monitoring and subsurface imaging, due to the utilization of sensitive sensors and modern techniques like seismic interferometry.

An improved characterization of passive seismic sources is beneficial to a better understanding of physical source properties, including both industry-related microseismicity and tectonic-related earthquakes. Microseismic monitoring is an important means to characterize small-scale fractures and reservoirs. Besides, microseismic events are crucial for mapping fault geometry, stress changes, fluid migration, and identifying seismogenic mechanisms. Passive seismic sources also play an important role in characterizing velocity structures by tomographic techniques. However, there are still many new challenges and opportunities in this field. For example, the full potential of dense arrays requires further exploration, the influence of different factors on source characterization at different scales has not been thoroughly studied, and the applicability and performance of machine learning algorithms in seismic source inversion and imaging require more investigations.

Progress in the Research Topic

The introduced Research Topic was organized to collect theoretical and methodological progress related to passive seismic source characterization associated with different scenarios, and promote development and application of advanced seismic source imaging and inversion at different scales. There are 11 papers from 59 authors in the Research Topic. We summarize the contributions as three aspects and provide comments on the related prospects.

Microseismic data processing and inversion

To better understand the impacts of model parameters on microseismic location, Zheng et al. analyze the sensitivities for anisotropic parameters and event locations in a vertical transversely isotropic (VTI) media. Yu et al. introduce a novel probabilistic method of P-wave polarization analysis for receiver orientation and event back-azimuth estimation in downhole microseismic monitoring. The method can improve the accuracy of the receiver orientation angles and event back-azimuths. Anikiev et al. propose to use a feed-forward artificial neural network (ANN) for microseismic source location by training it on synthetic travertine data. The method is suitable for monitoring areas with no previously observed microseismicity. Real data examples demonstrate the method is efficient and exhibits a high location accuracy. Adinolfi et al. design a software platform, TREMOR, for efficient and reliable characterization of microseismicity. The platform integrates several open-source seismological algorithms and has great potential for natural or induced microseismicity monitoring.

Advanced and comprehensive techniques are urgently needed to tackle the challenges of a large data volume, low signal-to-noise ratio, and high frequency components associated with microseismic data. Machine learning algorithms can help achieve more efficient and reliable microseismic event detection and source characterization. More integrated workflows will be proposed to promote microseismic processing and interpretation.

Natural earthquake studies

Zhou et al. investigate velocity changes associated with the 2021 M_S 6.4 Yangbi earthquake by passive seismic interferometry, which is based on cross-correlation and autocorrelation of continuous ambient noise waveforms. They interpret the velocity changes as a combined effect of near-surface physical damage and static stress changes. Sun et al. perform a three-dimensional (3D) P-wave velocity structure analysis and seismic relocation using double-difference tomography based on over 13,000 earthquakes in the Yunnan area, China. The tomography results indicate that the Yangbi earthquake might have been related to the intrusion of the soft material flow. Song et al. evaluate the effects of 3D velocity heterogeneity on source mechanism inversion, and present an improved moment tensor catalog based on 3D full-waveform simulations in the southern Korean Peninsula (KP). They conclude that improved source mechanisms could benefit a reliable assessment of seismic hazards in regions with complex structures and sedimentary basins. Luo et al. adopt the natural orthogonal method to calculate the strain fields of 3 Ms > 6 earthquakes in Menyuan, Qinghai, China. They reveal that the method could help obtain the spatiotemporal anomalies of strain field preceding strong earthquakes, when combined with numerical simulations.

Natural earthquakes are important data sources for subsurface velocity imaging, and strong earthquakes are disasters that can directly endanger human safety. Along with dense monitoring networks and comprehensive geological knowledge, seismic imaging and inversion can help us reveal velocity anomalies in detail and better understand seismogenic mechanisms. More reliable seismic processing is needed to achieve more reasonable interpretation, timely hazard evaluation, and effective earthquake prediction.

Advanced techniques associated with passive seismic sources

Hu et al. propose the Waveform Energy Focusing Tomography (WEFT) method for passive seismic tomography. The method updates the velocity model by maximizing the stacking energy of the moment time functions and can provide an intermediate and more accurate velocity model for subsequent inversion. Anyiam et al. apply Vp/Vs consistency-constrained double-difference seismic tomography to determine high-resolution velocity models and constructed a structural framework for induced seismicity in the southern Sichuan Basin, China. The 3D crustal velocity analyses show that seismicity beneath the Changing salt mining area and the Xingwen shale gas block are caused by unique inducing mechanisms. Lecoulant et al. attempt to invert seismic moment tensors of induced microearthquakes recorded by distributed acoustic sensing (DAS) observations. They develop the strain-based forward modeling and prove the reliability of the method with both synthetic and field data.

Advanced techniques have been successfully utilized for source and structure characterization varying from induced microearthquakes to natural regional earthquakes. Novel algorithms and methodologies are still needed to handle new data acquisitions, such as DAS and highly dense networks in more complex environments.

Author contributions

LL: Conceptualization, Funding acquisition, Project administration, Writing–original draft. FS: Conceptualization, Investigation, Writing–review and editing.

Funding

This study was supported by the Natural Science Foundation for Excellent Young Scholars of Hunan Province, China (2022JJ20057) and Central South University Innovation-Driven Research Programme (2023CXQD063).

Acknowledgments

We thank the various authors for submitting their work to this Research Topic and the reviewers who helped to review individual contributions.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.