Australia's National Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Baseline Seismicity of Beetaloo Basin – Interim Report 2

November 2024

Citation

Saygin, E, Qashqai MT and Guo, P (2024) Baseline Seismicity of Beetaloo Basin-Interim Report 2. CSIRO, Australia.

Copyright

© Commonwealth Scientific and Industrial Research Organisation 2024. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO.

Important disclaimer

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

CSIRO is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document please contact csiro.au/contact.

Acknowledgement

This research has been funded through CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA) with contributions from the Australian Government's Department of Industry, Science, Energy and Resources. GISERA is a collaboration between CSIRO, Commonwealth, state and territory governments and industry established to undertake research on the impacts of onshore gas exploration and development on the environment, and the socio-economic costs and benefits. For information about GISERA's governance structure, projects and research findings visit https://gisera.csiro.au.

We sincerely thank Geoscience Australia for deploying and maintaining the Beetaloo Seismic Network and making the data freely available to everyone. We also thank Dr Trevor Allen from GA Geoscience Australia and Prof. Brian L.N. Kennett (The Australian National University) for the earlier discussions about the interpretation of results.

Summary

In this interim report, we outline our activities for Task 5. In Task 5, we analysed all available continuous passive seismic data collected by Geoscience Australia across the Beetaloo Basin to detect and locate any seismicity within the basin and build a background seismicity profile. We used state-of-the-art machine learning-based detection methods to identify and locate earthquake-generated signals. We detected several events with magnitudes ranging from 2.4 to 2.7, originating from the McArthur River Mine, approximately 230 km away from the centre of the array, due to blasting activities within the mine.

Despite not detecting any measurable natural seismicity within the basin, we argue that the lack of detected seismicity does not indicate that the region is seismically quiet, especially given the complicated intraplate seismicity observed across Australia. This seismicity often manifests as aperiodic activity with prolonged quiet periods lasting several thousand to tens of thousands of years (Clark et al., 2012).

Introduction

In the first interim report, we benchmarked and reported the quality of the seismic data collected by the Beetaloo Seismic Network by conducting probabilistic noise processing. We also developed and fine-tuned seismic detection workflows and applied them to a subset of data. In the last part, we performed 3D waveform simulations with event parameters from a real earthquake that occurred around Tennant Creek to measure the evolution of the waveforms across the network. Our seismic detection workflow detected far-field events coming from the Fiji/Tonga regions and the McArthur River Mine, which is east of the network. In addition to these events, we also observed some very weak motion, which neither looked like mine blasting nor distant earthquakes, but due to the very low signal-to-noise ratios, we could not necessarily locate them.

In this interim report, we used all available seismic data recorded between 2019 and 2024 and applied the same workflow for earthquake detection and location. We found that all the locally detected events originated from the McArthur River Mine with very similar initiation times and magnitudes. Due to the proximity of the network to the mine, only blasts with equivalent local earthquake magnitudes of 2.29 and upwards were detected. Meanwhile, no natural seismicity was detected within the basin. However, the lack of detected seismicity is a function of sensor spacing, which is around 110 km, and the magnitude of those events if they exist, as well as the seismicity patterns observed in most of Australia, which are aperiodic and separated by long quiet periods of activity. Therefore, we argue that the apparent lack of seismicity in the basin does not remove the risk but requires a much more detailed study to quantify those very low magnitude natural seismic events within the basin.

Seismic Detection & Location

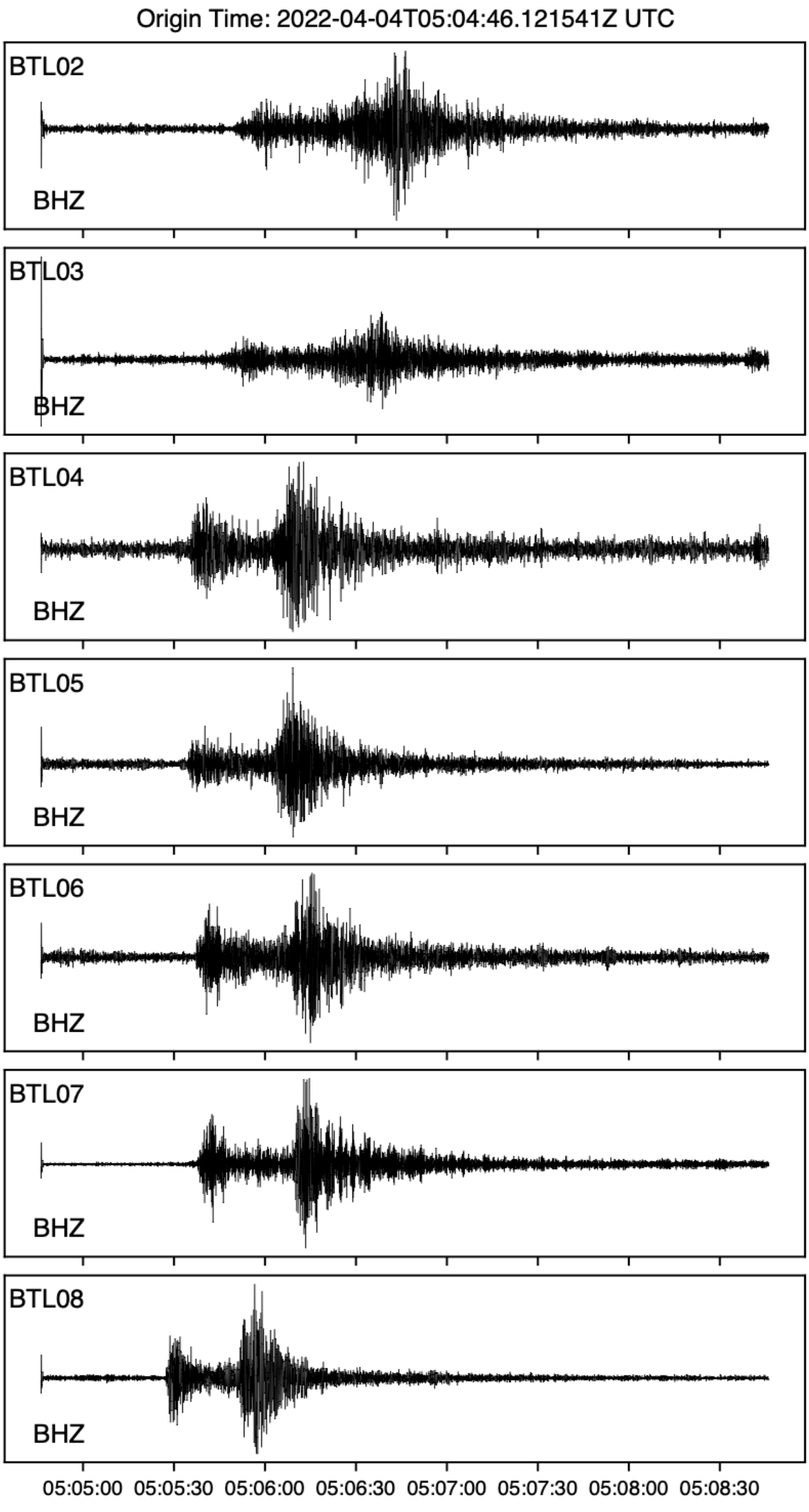
Seismic detection involves identifying earthquake signals from a range of non-earthquake signals and background noise recorded by a seismic sensor. Phase picking, on the other hand, refers to the process of identifying the arrival times of distinct seismic phases, such as the P-wave and S-wave, within an earthquake signal. These phases contain information about an earthquake and are used to determine its location.

We use a deep-learning workflow by Zhu & Beroza (2019) and Mousavi et al. (2020) for the simultaneous detection of earthquake signals and picking of P and S phases of the detected signals. This model is highly efficient in detecting and characterising smaller and more seismic events. The EQTransformer by Mousavi et al. (2020) generates results when at least one phase, either P or S, has a probability exceeding a user-defined threshold within a time window that has a high likelihood of representing an earthquake. Here, we used threshold values of 0.001, 0.01, and 0.1 for detection, P-picking, and S-picking, respectively. We applied this workflow to all available data between 2019 and 2024 recorded by Geoscience Australia's Beetaloo Seismic Network (Glanville, 2019). For the velocity model, we used Chen et al. (2023), which is an Australia-wide seismic velocity model produced from seismic noise tomographic imaging previously by CSIRO scientists.

During this period, our workflow detected only four major events, all located in Glencore's McArthur River Mine (given in Table 1), which is approximately 200 km from the closest point of the array. These are large to very large mine blasts that have been properly registered by the network. Waveform plots for the vertical components of the events are given in Figures 1-4, and the location is shown in Figure 5. In Figure 5, we also show the yearly evolution of the array configuration, as some of stations were moved to increase the coverage. As the mine is quite far from the network, only very significant events were recorded. Although the outcome of this activity was not the intention of this study, these events show that the workflows are working as intended and are sensitive to seismicity as low as 2.29 and as far as 230 km from the centre of the array.

Event No	Origin Time (UTC)	Latitude (DD)	Longitude (DD)	Local Magnitude (Ml)
1	2022-04-04T05:04:46.121541Z	-16.601	136.248	2.75
2	2023-06-04T05:10:18.617616Z	-16.672	136.239	2.74
3	2023-11-13T05:25:57.708278Z	-16.288	136.195	2.40
4	2024-04-18T05:40:22.917387Z	-16.411	136.238	2.29

Table 1: Details of the detected seismic events between 2019 and 2024. All these signals originate from the McArthur River Mine during their large blasting activities. Note the similar origin time for each blast, which is between 14:30 and 15:10 local time.



Origin Time: 2022-04-04T05:04:46.121541Z UTC
BTL02
BHZ
BTL03
BHZ
BTL04
BHZ
BTL05
BHZ
BTL06
BHZ
BTL07
BHZ
BTL08
BHZ
05:05:00 05:05:30 05:06:00 05:06:30 05:07:00 05:07:30 05:08:00 05:08:30

Figure 1: The waveforms of Event 1 recorded across the Beetaloo Basin Seismic Network, originating from the McArthur River Mine. Each waveform was filtered between 2 and 10 Hz, and the estimated local magnitude is 2.75.

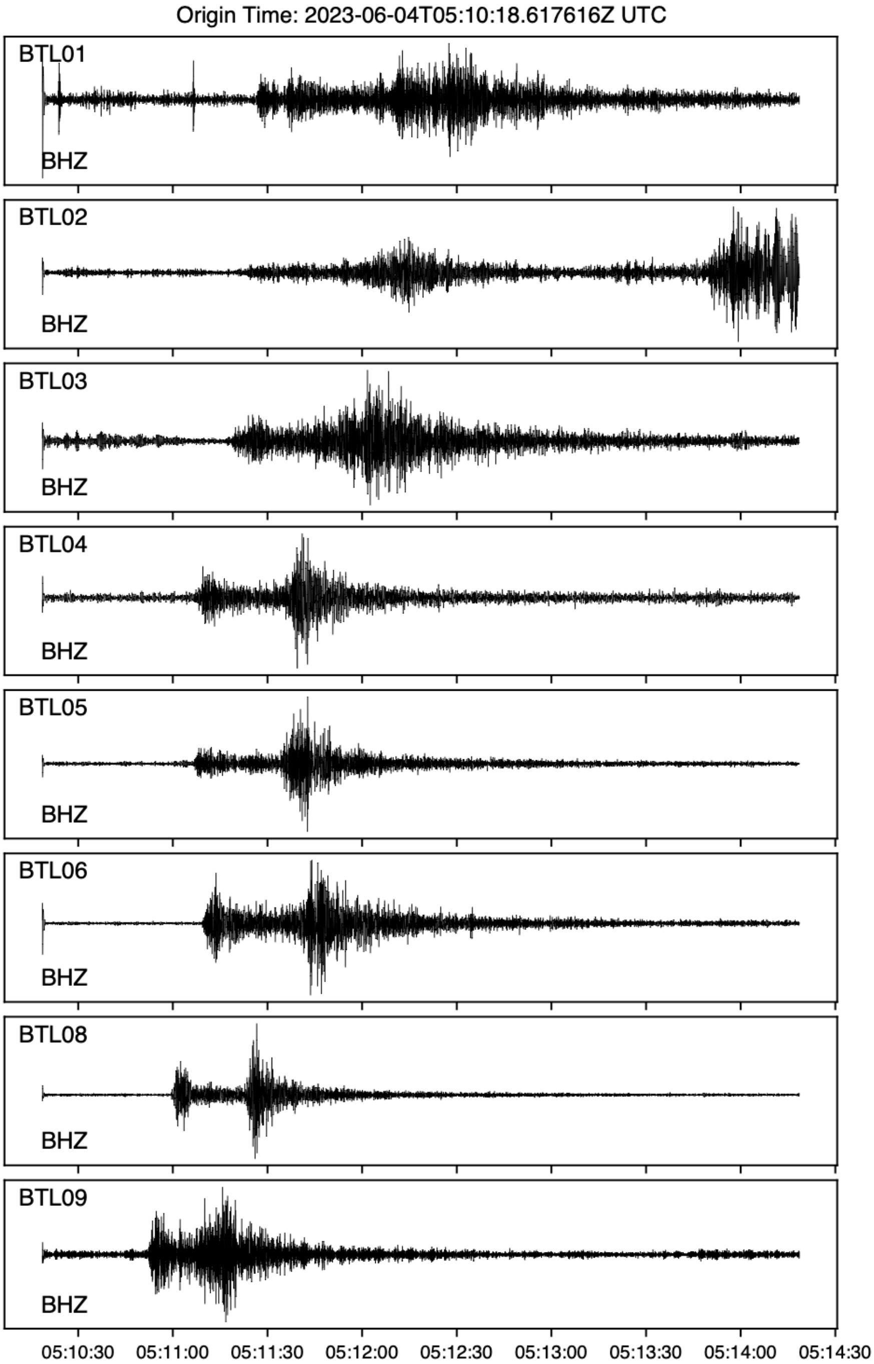


Figure 2: The waveforms of Event 2 recorded across the Beetaloo Basin Seismic Network, originating from the McArthur River Mine. Each waveform was filtered between 2 and 10 Hz, and the estimated local magnitude is 2.74.

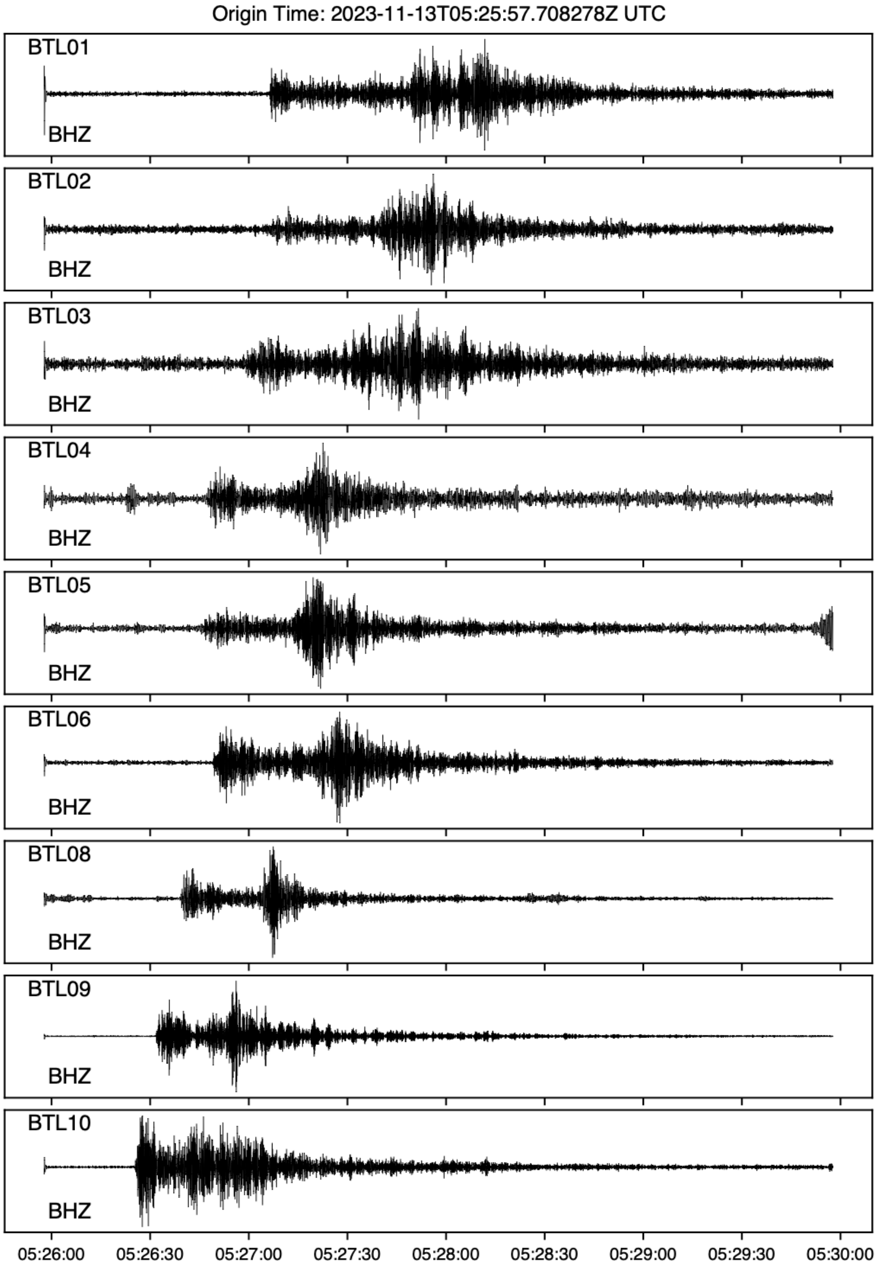


Figure 3: The waveforms of Event 3 recorded across the Beetaloo Basin Seismic Network, originating from the McArthur River Mine. Each waveform was filtered between 2 and 10 Hz, and the estimated local magnitude is 2.74.

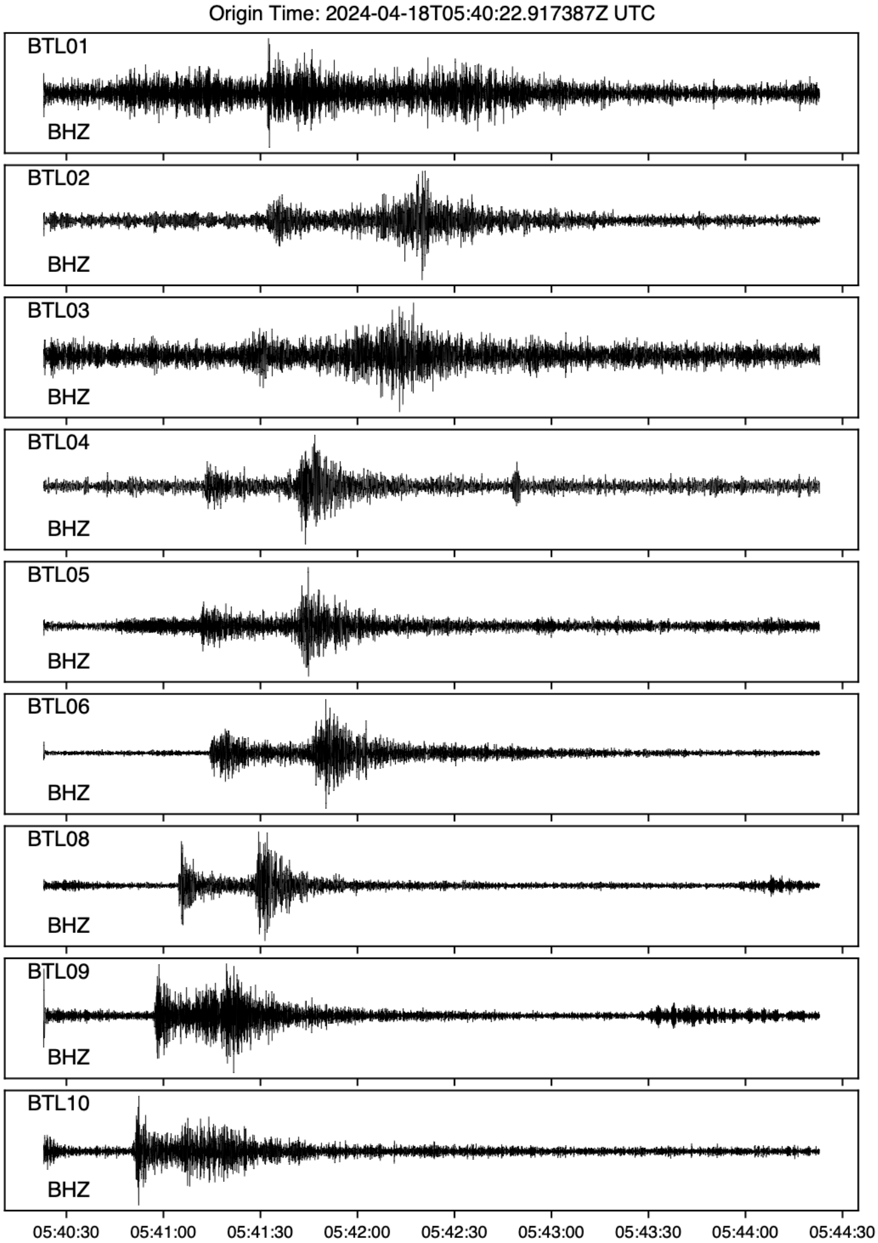


Figure 4: The waveforms of Event 4 recorded across the Beetaloo Basin Seismic Network, originating from the McArthur River Mine. Each waveform was filtered between 2 and 10 Hz, and the estimated local magnitude is 2.29.

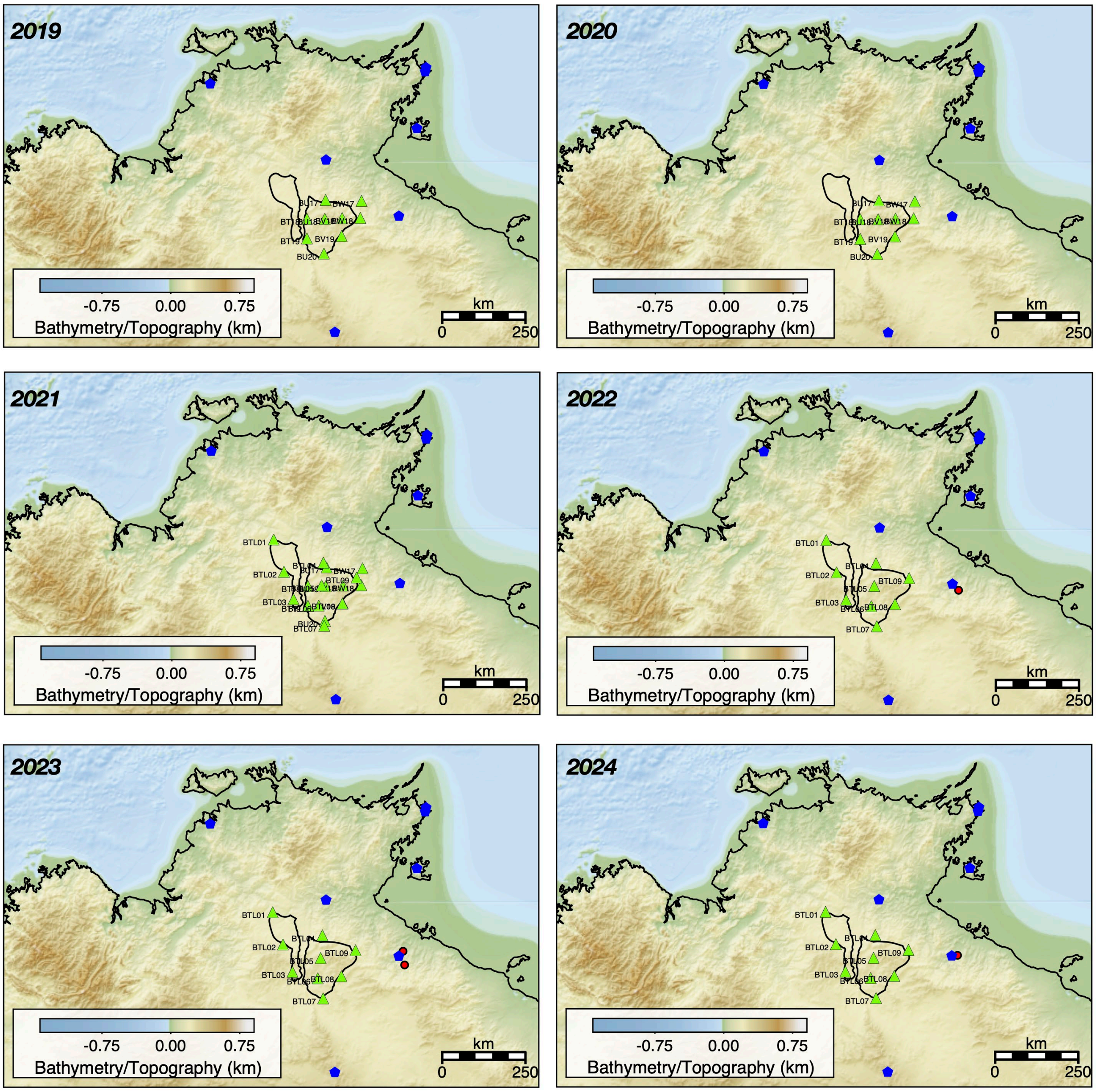


Figure 5: Yearly evolution of the Beetaloo Seismic array and also detected events between 2019 and 2024. The locations of the detected events are marked with red circles. Green triangles indicate the locations of Beetaloo Seismic Network stations, and blue pentagons show the active mine sites. The McArthur River Mine is located near the red circles. The background topography and bathymetry are derived from ETOPO1 (Amante et al., 2009).

Summary

In this interim report, we use all available seismic data from the Beetaloo Seismic Network, deployed and operated by Geoscience Australia, to detect and document local seismic activity within the basin. During the analysis period between 2019 and 2024, we only detected major mining blasting activity coming from the east of the network, approximately 230 km from the centre of the network.

The ‘lack’ of detected seismic activity within the basin should be interpreted in light of the network sensitivity, where small magnitude earthquakes (e.g., Ml < 1) cannot be fully recorded due to background noise levels. With increasing distance, it becomes harder to differentiate signal from noise because of attenuation. Additionally, the nature of intraplate seismicity observed across Australia is aperiodic and separated by very long quiet periods of several tens of thousands of years. In the final report, we will document our suggestions and propose follow-up studies with a tailored dense seismic array with shorter separation to detect smaller magnitude events. We will also analyse high-resolution satellite images to detect surface ruptures from past large earthquakes to quantify the probabilities of recurrence rates.

References

Amante, C. and B.W. Eakins, 2009. ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24. National Geophysical Data Center, NOAA. doi:10.7289/V5C8276M [July 2024]

Chen, Y., Saygin, E., Kennett, B., Qashqai, M. T., Hauser, J., Lumley, D., & Sandiford, M. (2023). Next-generation seismic model of the Australian crust from synchronous and asynchronous ambient noise imaging. *Nature Communications*, *14*(1), 1192.

Clark, D., McPherson, A., & Van Dissen, R. (2012). Long-term behaviour of Australian stable continental region (SCR) faults. *Tectonophysics*, *566*, 1-30.

Glanville, H. (2019). *Beetaloo Seismic Monitoring Project* [Data set]. International Federation of Digital Seismograph Networks. https://doi.org/10.7914/SN/2O_2019

Mousavi, S. M., Ellsworth, W. L., Zhu, W., Chuang, L. Y., & Beroza, G. C. (2020). Earthquake transformer—an attentive deep-learning model for simultaneous earthquake detection and phase picking. *Nature communications*, *11*(1), 3952.

Zhu, W., & Beroza, G. C. (2019). PhaseNet: a deep-neural-network-based seismic arrival-time picking method. *Geophysical Journal International*, *216*(1), 261-273.

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

Contact us

1300 363 400
+61 3 9545 2176
csiro.au

For further information

1300 363 400
gisera.csiro.au

GISERA is a collaboration between CSIRO, Commonwealth and state governments and industry established to undertake publicly-reported independent research. The purpose of GISERA is to provide quality assured scientific research and information to communities living in gas development regions focusing on social and environmental topics including: groundwater and surface water, greenhouse gas emissions, biodiversity, land management, the marine environment, and socio-economic impacts. The governance structure for GISERA is designed to provide for and protect research independence and transparency of research.