Australia's National Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Baseline seismic monitoring of the Canning Basin

Interim Reports 2 & 3

June 2025

Citation

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Summary

The combined interim report provides an update on activities related to Task 2 (Establishment of a Data Centre and Detection Workflow) and Task 3 (Development of the Seismicity Publication Platform) of the baseline seismic monitoring project in the Canning Basin.

For Task 2, we developed and deployed a fully operational data processing system that automatically retrieves seismic waveform data from the GSWA network, as well as from national and international repositories. Using recent machine learning-based detection tools such as EQTransformer and PhaseNet, the system can detect, pick, and locate small-magnitude seismic events across the region. Events are automatically processed and catalogued, with key information such as origin time, location, magnitude, and depth extracted and stored. ML-based methods such as EQTransformer and PhaseNet have demonstrated improved sensitivity to low SNR events and reduced false positives compared to traditional STA/LTA approaches (Zhu & Beroza, 2019).

Task 3 focused on making these results accessible through a user-friendly, web-based interface. A prototype publication platform was built using open source platform Streamlit, allowing users to view earthquake locations on interactive maps, query event metadata, and download catalogues. The platform includes both a heat map and cluster map view of events, with search filters by time, magnitude, and depth. The system is lightweight, does not require dedicated hardware, and has been demonstrated successfully on standard desktop machines.

Together, these two components form the core of the baseline seismic monitoring capability for the region. The workflows established here will allow for ongoing tracking of background seismicity and form the reference against which any future changes in seismic activity can be assessed.

Publication Dissemination Platform

Task 3 involved the development of a public-facing dissemination platform using Streamlit , an open-source Python framework that enables interactive applications from Python scripts. This web interface, which is currently in a **prototype stage**, includes:

- A heat map for event density.
- A cluster map with zoom functionality.
- A downloadable, filterable event catalogue with fields for time, magnitude, depth, and coordinates.

The platform is lightweight and can be operated on standard desktop hardware. The goal was to provide public access to the seismicity catalogue generated in Task 2, in a transparent and accessible format.

The interface consists of two main map panels (Figure 1). The first panel displays a **heat map** showing the spatial density of detected events. This provides an intuitive visual summary of seismic activity across the selected region. The second panel presents the same events in a **clustered format**, where nearby events are grouped to improve readability when zoomed out. Both maps use OpenStreetMap, which is an open-source data as the base layer and support zoom and pan functionality.

Below the maps, a **tabular view** (Figure 1) lists all detected events, including event ID, time, magnitude, depth, and coordinates. This table can be filtered using input boxes in the left-hand panel, allowing users to constrain events by magnitude, depth, and date range. The table is downloadable in plain text (.csv) format.

Figure 1 Screenshot of the Streamlit-based interface showing the earthquake **heat map** (left) and **cluster map** (right). The heat map highlights areas with high concentrations of detected events, while the cluster map groups closely spaced events for easier visualisation. The lower panel of the interface displays a searchable, filterable **event catalogue**. Users can download the catalogue and apply custom filters based on time, magnitude, and depth.

The bottom panel of the interface can also be **expanded** to full screen using a resize button (Figure 2), allowing for detailed inspection of the earthquake catalogue mainly for the specialist audience e.g., earth scientists.

	FID	earthquake_id	azimuthal_gap	azimuth_	depth	depth_u	description	epicentral_time	evaluation_mode	evaluation_status
0	earthquakes.fid--e1a0f16_19264f4a3b4_-33d8	683716	46.6300	48.6802	5.0000	0.0000	NE of Gnowangerup, WA	2023-01-05T13:12:17.863	manual	reviewed
4	earthquakes.fid--e1a0f16_19264f4a3b4_-33d4	683521	115.0501	79.5862	5.0000	0.0000	Beacon, WA	2022-12-09T14:53:54.76	manual	reviewed
5	earthquakes.fid--e1a0f16_19264f4a3b4_-33d3	676837	191.9568	26.0080	1.2254	2.9681	NW of Beacon, WA	2021-08-12T11:08:36.251	manual	reviewed
7	earthquakes.fid--e1a0f16_19264f4a3b4_-33d1	679192	171.7293	89.1856	1.0192	2.8637	E of Darkan, WA	2022-01-11T14:58:51.387	manual	reviewed
8	earthquakes.fid--e1a0f16_19264f4a3b4_-33d0	679304	139.4428	22.3502	5.0000	0.0000	E of Darkan, WA	2022-01-19T18:30:10.734	manual	reviewed
12	earthquakes.fid--e1a0f16_19264f4a3b4_-33cc	682488	149.0910	76.0918	5.0000	0.0000	E of Darkan, WA	2022-09-11T23:31:29.683	manual	reviewed
13	earthquakes.fid--e1a0f16_19264f4a3b4_-33cb	691700	267.5028	17.0464	3.3324	3.2358	SE of Wyalkatchem, WA	2024-08-16T02:25:45.701	manual	reviewed
14	earthquakes.fid--e1a0f16_19264f4a3b4_-33ca	682553	148.3339	81.2546	5.0000	0.0000	E of Darkan, WA	2022-09-16T07:07:12.361	manual	reviewed
18	earthquakes.fid--e1a0f16_19264f4a3b4_-33c6	683259	155.8823	22.2264	0.5340	2.3647	Dalwallinu, WA	2022-11-21T17:16:34.834	manual	reviewed
19	earthquakes.fid--e1a0f16_19264f4a3b4_-33c5	690540	117.8388	73.3549	0.7754	3.1158	SE of Wyalkatchem, WA	2024-06-01T02:04:58.99	manual	reviewed
20	earthquakes.fid--e1a0f16_19264f4a3b4_-33c4	676034	92.6306	113.2909	0.7678	2.2876	N of Cunderdin, WA	2021-06-29T07:05:00.502	manual	reviewed
21	earthquakes.fid--e1a0f16_19264f4a3b4_-33c3	679485	98.7569	61.7956	5.0000	0.0000	E of Darkan, WA	2022-01-25T21:40:10.881	manual	reviewed
23	earthquakes.fid--e1a0f16_19264f4a3b4_-33c1	675608	162.6336	89.4478	5.0000	0.0000	Meckering, WA	2021-05-27T08:32:05.083	manual	reviewed
24	earthquakes.fid--e1a0f16_19264f4a3b4_-33c0	676865	201.7529	41.0204	0.5180	5.1747	NW of Beacon, WA	2021-08-10T07:22:44.406	manual	reviewed
25	earthquakes.fid--e1a0f16_19264f4a3b4_-33bf	684713	152.6941	68.6695	5.0000	0.0000	E of Darkan, WA	2023-03-20T19:09:06.524	manual	reviewed
26	earthquakes.fid--e1a0f16_19264f4a3b4_-33be	686082	108.0186	133.6780	1.6713	2.7454	Corrigin, WA	2023-06-23T22:14:21.101	manual	reviewed
27	earthquakes.fid--e1a0f16_19264f4a3b4_-33bd	688918	191.8110	159.0824	5.0000	0.0000	Esperance, WA	2024-01-28T04:55:53.728	manual	reviewed
29	earthquakes.fid--e1a0f16_19264f4a3b4_-33bb	680247	85.6157	76.0729	1.3913	1.9316	SW of Koorda, WA	2022-03-15T13:34:55.554	manual	reviewed
30	earthquakes.fid--e1a0f16_19264f4a3b4_-33ba	691894	66.2799	89.4305	5.0000	0.0000	SE of Wyalkatchem, WA	2024-08-22T00:30:26.99	manual	reviewed
31	earthquakes.fid--e1a0f16_19264f4a3b4_-33b9	684118	148.4055	85.2245	3.9620	2.7529	SE of Darkan, WA	2023-02-07T10:41:59.313	manual	reviewed
33	earthquakes.fid--e1a0f16_19264f4a3b4_-33b7	683209	222.7087	85.0133	1.4590	2.8478	Mukinbudin, WA	2022-11-18T01:14:02.886	manual	reviewed
34	earthquakes.fid--e1a0f16_19264f4a3b4_-33b6	684490	53.3639	67.5709	5.0000	0.0000	Beacon, WA	2023-03-03T20:26:44.373	manual	reviewed
35	earthquakes.fid--e1a0f16_19264f4a3b4_-33b5	684060	147.8150	75.7317	5.0000	0.0000	E of Darkan, WA	2023-02-06T14:05:53.665	manual	reviewed
36	earthquakes.fid--e1a0f16_19264f4a3b4_-33b4	682222	62.6817	71.7702	0.6117	2.0777	Brookton, WA	2022-08-26T20:07:47.316	manual	reviewed
37	earthquakes.fid--e1a0f16_19264f4a3b4_-33b3	689089	74.8177	94.3900	5.0000	0.0000	E of Darkan, WA	2024-02-10T18:18:37.413	manual	reviewed
39	earthquakes.fid--e1a0f16_19264f4a3b4_-33b1	676896	93.4604	57.4718	4.3569	1.6574	SW of Koorda, WA	2021-08-14T04:42:31.988	manual	reviewed
40	earthquakes.fid--e1a0f16_19264f4a3b4_-33b0	683456	115.9863	106.3567	5.0000	0.0000	SE of Koorda, WA	2022-12-03T17:35:19.926	manual	reviewed
42	earthquakes.fid--e1a0f16_19264f4a3b4_-33ae	678791	119.2537	64.7834	1.6784	2.7095	Dumbleyung, WA	2021-12-19T21:39:40.719	manual	reviewed

	event_creation_time	event_id	event_modification_time	latitude	longitude	mb	md	mla	ms	mw	mww	mwp	mwmwp	minimu	maximun	nearest_station	origin_id
0	2023-01-05T05:13:28.294	ga2023ahtgqs	2023-01-06T03:39:40.831	-33.7834	118.3395	<NA>	<NA>	4.5297	<NA>	<NA>	<NA>	6.4332	6.4077	0.0927	19.4063	0.0927	20230106
4	2022-12-09T06:54:55.086	ga2022yeibro	2022-12-11T20:42:18.245	-30.4538	117.7605	<NA>	<NA>	1.9910	<NA>	<NA>	<NA>	<NA>	<NA>	0.1176	3.8771	0.1176	20221211
5	2021-08-12T03:09:43.057	ga2021ptpeur	2021-08-12T21:57:57.991	-30.2465	117.7287	<NA>	<NA>	2.0164	<NA>	<NA>	<NA>	<NA>	<NA>	0.0944	1.8813	0.0944	20210812
7	2022-01-11T07:00:10.505	ga2022asxdtk	2022-01-11T20:26:32.89	-33.3782	116.9260	<NA>	<NA>	2.3158	<NA>	<NA>	<NA>	<NA>	<NA>	0.5204	4.3633	0.5204	20220111
8	2022-01-19T10:31:04.589	ga2022bhvyye	2022-01-19T20:39:40.965	-33.3210	117.0885	<NA>	<NA>	3.4558	<NA>	<NA>	<NA>	<NA>	<NA>	0.4121	16.9342	0.4121	20220119
12	2022-09-11T15:32:26.628	ga2022rxppjj	2022-09-12T21:41:25.623	-33.3726	116.9847	<NA>	<NA>	2.0750	<NA>	<NA>	<NA>	<NA>	<NA>	0.4923	1.8914	0.4923	20220912
13	2024-08-15T18:26:41.678	ga2024qccmqi	2024-08-15T21:02:18.802	-31.3351	117.5826	<NA>	<NA>	2.2330	<NA>	<NA>	<NA>	<NA>	<NA>	0.2948	1.6144	0.2948	20240815
14	2022-09-15T23:08:16.628	ga2022sfnpov	2022-09-16T05:47:19.12	-33.3620	116.9934	<NA>	<NA>	2.3298	<NA>	<NA>	<NA>	<NA>	<NA>	0.4796	1.8790	0.4796	20220916
18	2022-11-21T09:17:32.108	ga2022wxlsud	2022-11-22T00:27:41.471	-30.1792	117.2924	<NA>	<NA>	1.9928	<NA>	<NA>	<NA>	<NA>	<NA>	0.4376	2.0203	0.4376	20221122
19	2024-05-31T18:06:00.616	ga2024ksopwe	2024-06-02T21:47:42.348	-31.4222	117.5122	<NA>	<NA>	2.1879	<NA>	<NA>	<NA>	<NA>	<NA>	0.2671	1.5189	0.2671	20240602
20	2021-06-28T23:05:43.519	ga2021mqnedz	2021-06-29T04:43:30.928	-31.3967	117.2101	<NA>	<NA>	2.3627	<NA>	<NA>	<NA>	<NA>	<NA>	0.5040	2.5322	0.5040	20210629
21	2022-01-25T13:41:16.294	ga2022btcpxk	2022-01-26T22:41:31.022	-33.3239	117.0494	<NA>	<NA>	2.9508	<NA>	<NA>	<NA>	<NA>	<NA>	0.4259	9.6817	0.4259	20220126
23	2021-05-27T03:10:12.615	ga2021kibcdt	2021-05-27T03:10:12.855	-31.6451	116.9663	<NA>	<NA>	2.1214	<NA>	<NA>	<NA>	<NA>	<NA>	1.0506	2.9562	1.0506	20210527
24	2021-08-10T03:50:06.009	ga2021ppqgkh	2021-08-13T01:11:00.999	-30.2468	117.7065	<NA>	<NA>	2.0338	<NA>	<NA>	<NA>	<NA>	<NA>	0.1021	1.8664	0.1021	20210813
25	2023-03-20T11:10:41.426	ga2023foavgi	2023-03-20T22:36:40.768	-33.3684	117.0076	<NA>	<NA>	2.1302	<NA>	<NA>	<NA>	<NA>	<NA>	0.4804	1.8809	0.4804	20230320
26	2023-06-23T14:15:35.699	ga2023mgqymi	2023-06-25T22:56:45.97	-32.4538	117.7301	<NA>	<NA>	2.2090	<NA>	<NA>	<NA>	<NA>	<NA>	0.4164	2.1116	0.4164	20230625
27	2024-01-27T20:57:52.418	ga2024bxingj	2024-01-29T03:15:49.038	-33.7650	121.3932	<NA>	<NA>	2.6082	<NA>	<NA>	<NA>	<NA>	<NA>	2.4267	10.5724	2.4267	20240129
29	2022-03-15T05:35:46.852	ga2022felcwj	2022-03-15T23:22:10.222	-30.9510	117.2408	<NA>	<NA>	2.2769	<NA>	<NA>	<NA>	<NA>	<NA>	0.2372	4.4634	0.2372	20220315
30	2024-08-21T16:31:08.697	ga2024qmzaor	2024-08-21T23:29:42.273	-31.2862	117.6238	<NA>	<NA>	2.4796	<NA>	<NA>	<NA>	<NA>	<NA>	0.3243	4.7140	0.3243	20240821
31	2023-02-07T02:43:24.214	ga2023cqdgdu	2023-02-07T20:12:07.812	-33.3854	116.9988	<NA>	<NA>	2.4584	<NA>	<NA>	<NA>	<NA>	<NA>	0.4990	4.3816	0.4990	20230207
33	2022-11-17T17:14:55.999	ga2022wqsqsa	2022-11-17T19:51:34.334	-30.8814	118.3325	<NA>	<NA>	2.0584	<NA>	<NA>	<NA>	<NA>	<NA>	0.1881	1.7895	0.1881	20221117
34	2023-03-03T12:28:05.974	ga2023eiyber	2023-03-06T00:04:59.275	-30.4290	117.7681	<NA>	<NA>	2.6104	<NA>	<NA>	<NA>	<NA>	<NA>	0.0928	10.7594	0.0928	20230305
35	2023-02-06T06:07:32.789	ga2023coogbe	2023-02-06T23:43:50.708	-33.3726	117.0044	<NA>	<NA>	2.7018	<NA>	<NA>	<NA>	<NA>	<NA>	0.4854	4.3700	0.4854	20230206
36	2022-08-26T12:08:36.327	ga2022qtzftm	2022-08-28T22:00:20.207	-32.3583	116.9356	<NA>	<NA>	2.4321	<NA>	<NA>	<NA>	<NA>	<NA>	0.6228	5.8869	0.6228	20220828
37	2024-02-10T10:19:35.28	ga2024cwfohh	2024-02-11T22:45:47.022	-33.3603	117.0453	<NA>	<NA>	2.9858	<NA>	<NA>	<NA>	<NA>	<NA>	0.4610	9.6929	0.4610	20240211
39	2021-08-13T20:43:32.496	ga2021pwtvwj	2021-08-15T22:06:14.783	-30.9100	117.2674	<NA>	<NA>	2.4268	<NA>	<NA>	<NA>	<NA>	<NA>	0.2053	18.0279	0.2053	20210815
40	2022-12-03T09:36:30.509	ga2022xtnbmr	2022-12-04T23:04:31.112	-30.9186	117.7559	<NA>	<NA>	2.1170	<NA>	<NA>	<NA>	<NA>	<NA>	0.2213	4.3330	0.2213	20221204
42	2021-12-19T13:40:54.624	ga2021yxeudl	2021-12-20T21:55:00.532	-33.4573	117.6285	<NA>	<NA>	2.1000	<NA>	<NA>	<NA>	<NA>	<NA>	0.6210	1.8996	0.6210	20211220

Figure 2 The tabular event panel can be maximised for easier viewing using the resize button in the top-right corner. The table is showing technical details of each earthquake tailored for the specialists.

The left column of the interface (Figure 3) provides a search box for magnitude, depth, date ranges, where the catalogue can be filtered easily.

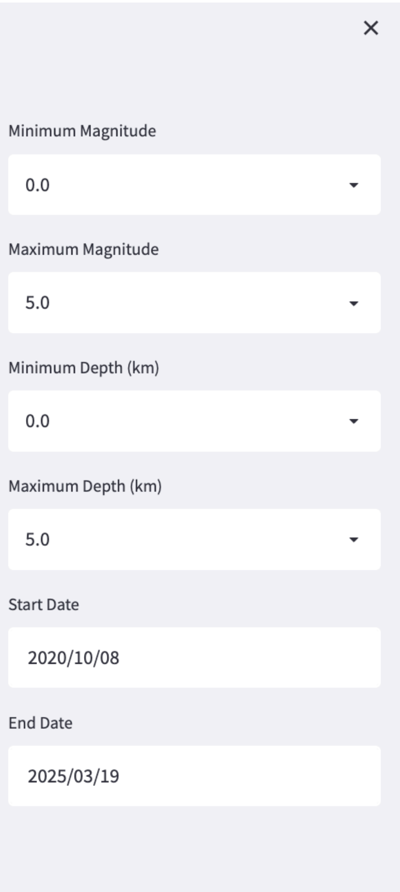

Figure 3: Search box for filtering based magnitude, depth, and date ranges.

Both maps can be interactively zoomed in & out. The heat map representation of the earthquake data updates itself, according to the zoom level and also the number of earthquakes and their magnitudes within the visualisation window (Figure 4).

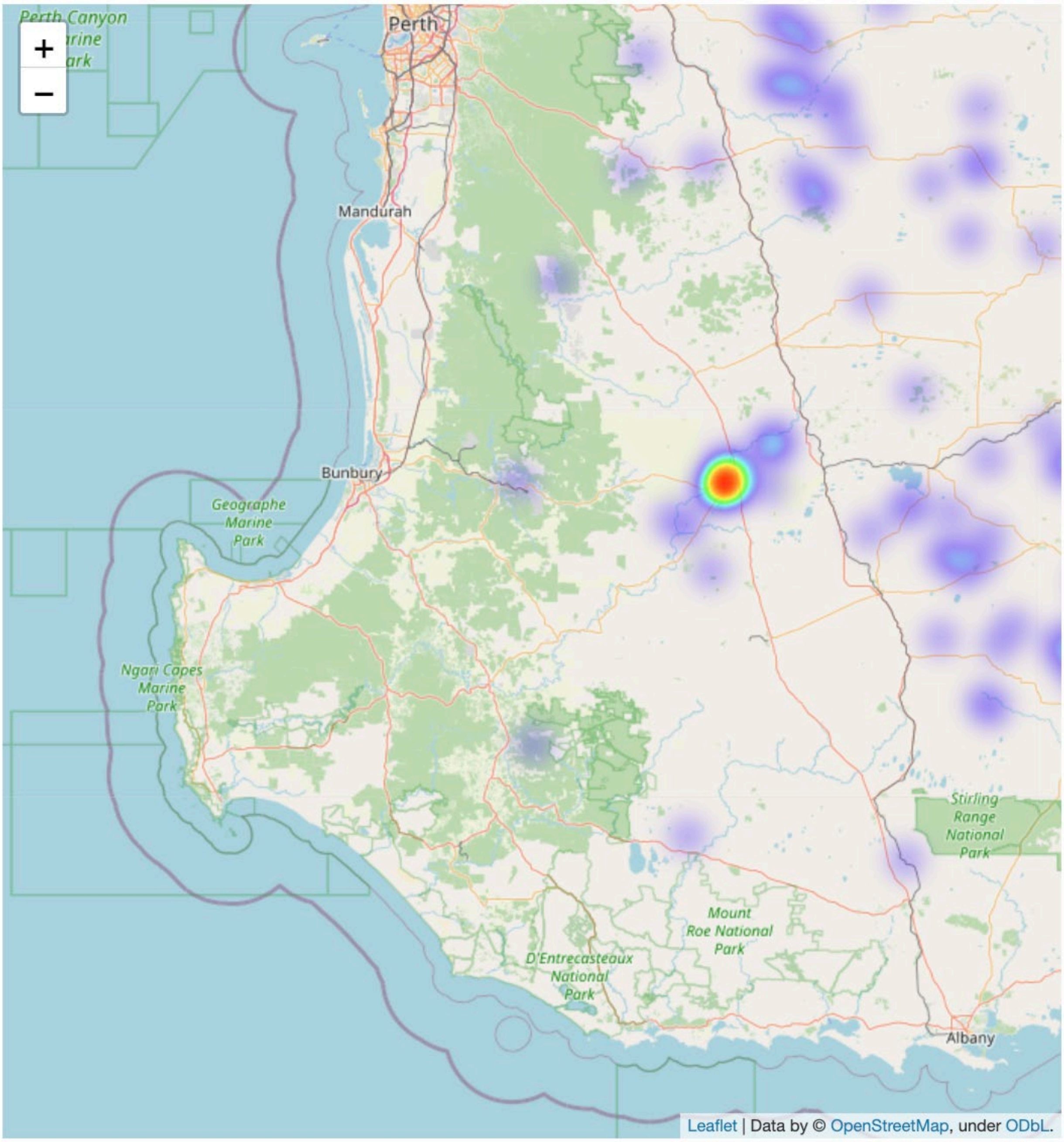

Figure 4: Zoomed-in version of the earthquake heat map.

The cluster map can be also interactively zoomed in and out to query earthquake information. By clicking blue pins corresponding to each earthquake, location coordinates, earthquake magnitude, hypocentre depth and the origin time can be obtained (Figure 5).

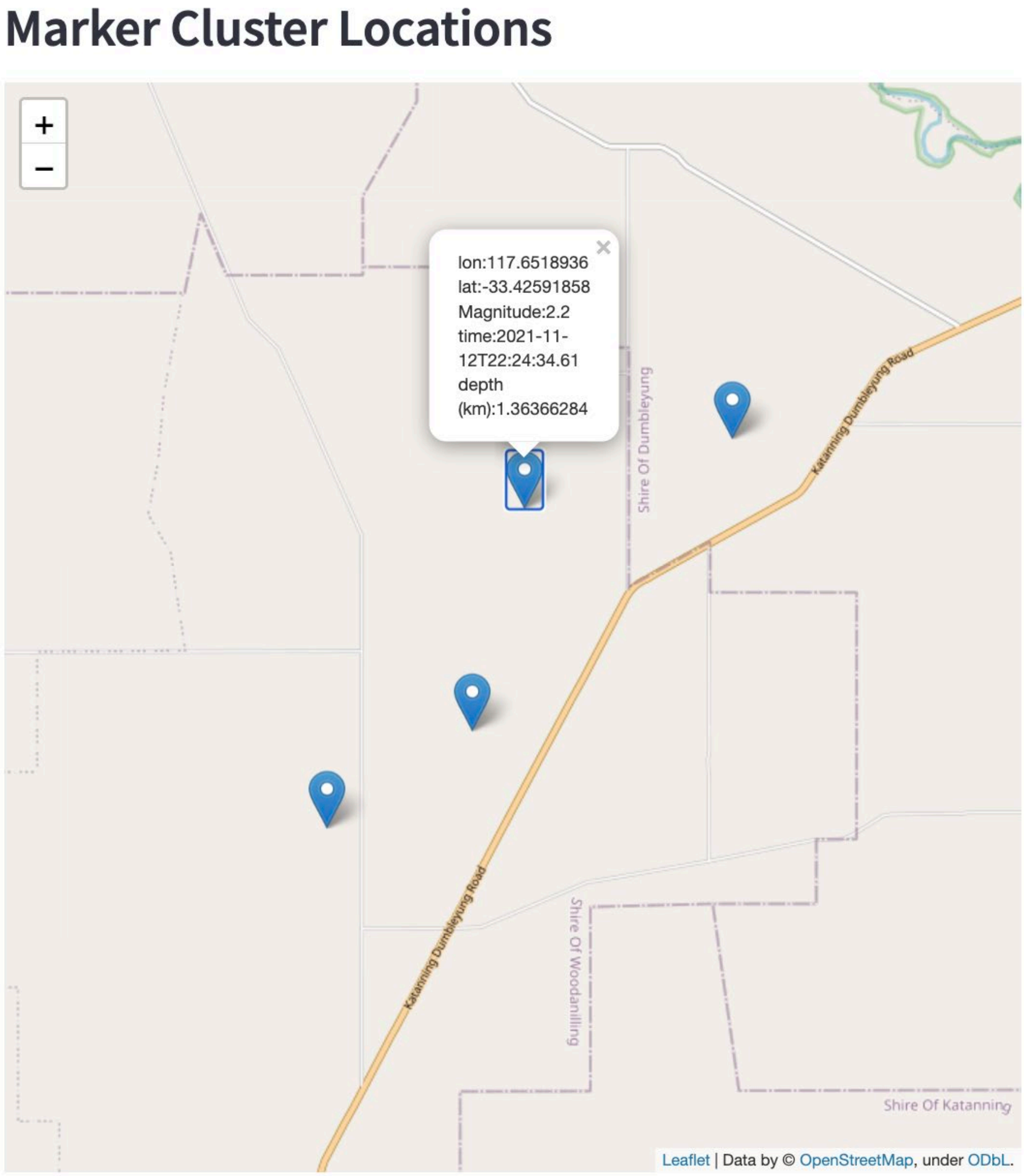

Figure 5: Example of metadata window triggered by clicking on an event marker in the cluster map. In the meta window, the spatial coordinates, hypocentre (depth), origin time (UTC-Coordinated Universal Time) and the magnitude of the selected event is shown.

In addition to its functionality, the platform is extremely lightweight and can be run on a desktop machine with minimal computational resources.

Conclusion

We designed a modern inter-active public information dissemination platform using purely open-source tools. This new platform does not require any ongoing fees from the server side, and is lightweight, meaning it requires minimum resources to be operational. The training session was delivered to the scientists of GSWA, and the platform will be transferred to their servers, once the infrastructure at their end becomes ready.

Seismicity

We analysed seismic data collected by GSWA and Geoscience Australia between July 2023 and July 2024. Data prior to this period was not used due to issues such as firmware errors (e.g., internal clock drift) and data loss from Tropical Cyclone Ellie (late December 2022 – early January 2023). These issues have now been retrospectively corrected by GSWA, and we will include an Annexure showing the list of the detected events by using the currently corrected data, post the completion of this project.

A map showing seismic station locations and operating mines is provided in Figure 6. A total of **9 events** were detected between July 2023 and July 2024 (see Table 1). Most detected events are not spatially correlated with mining/quarry operations, suggesting a natural origin. One event is located near an active quarry site with a magnitude of 2.4 and depth of ~9.5 km. However, a depth of ~9.5 km is atypical for quarry blasting, which occurs at much shallower depths (typically less than 1 km). To the south of the array, no events were detected, likely due to decreased network sensitivity outside the station perimeter.

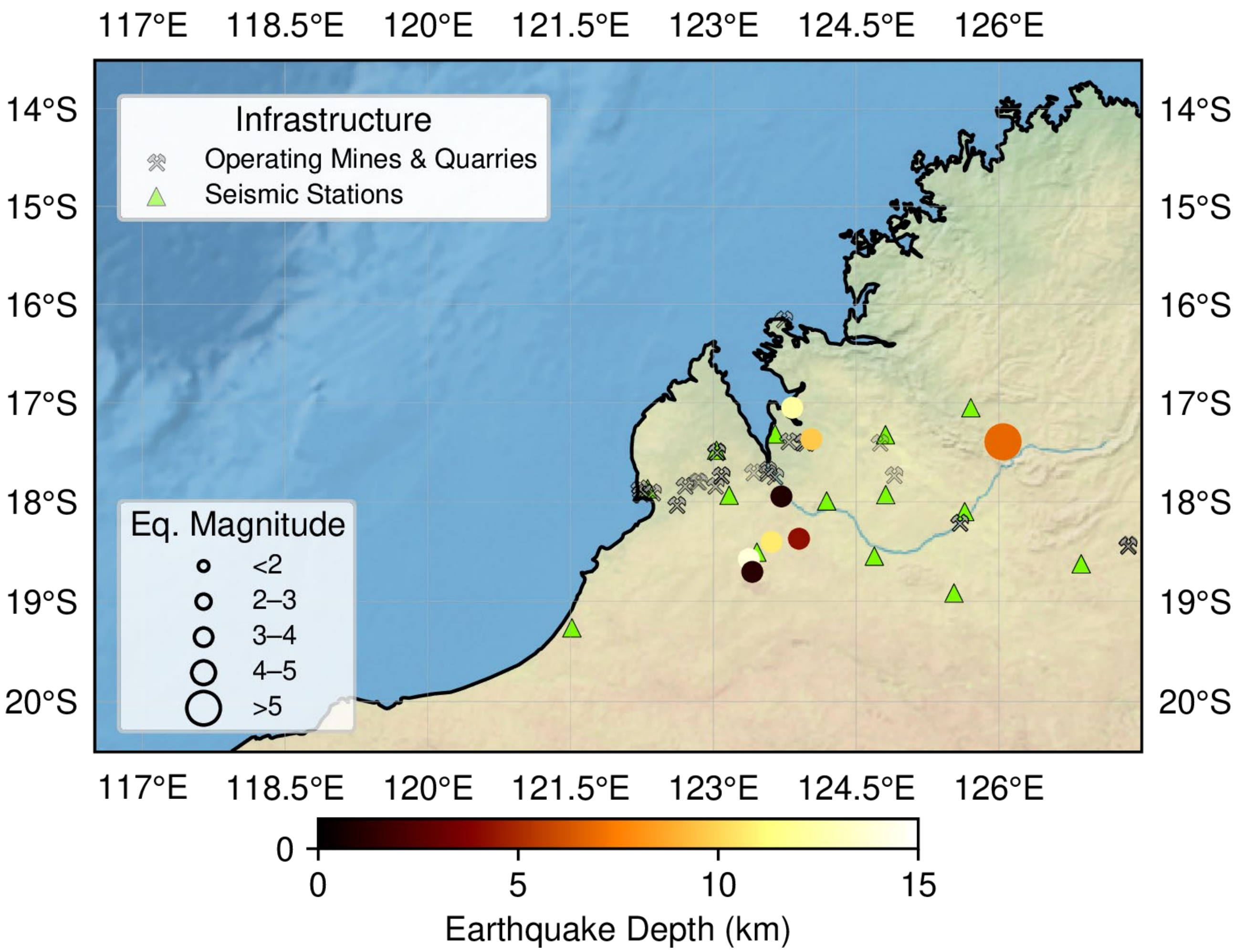

Figure 6 Map of seismic stations and detected events between July 2023 and July 2024. Operating mines and quarries are shown along with the seismic stations used in this study.

Origin Time (UTC)	Latitude (DD)	Longitude (DD)	Depth (km)	Magnitude (Ml)
2023-09-21T06:17:11.730000Z	-18.402	123.612	11.375	2.7
2023-10-21T01:51:17.040000Z	-17.068	123.830	12.757	2.5
2023-11-18T03:25:02.240000Z	-18.575	123.373	13.832	2.1
2023-11-22T04:47:23.190000Z	-17.945	123.714	0.943	2.1
2023-11-28T13:01:29.680000Z	17.031	123.823	12.212	2.3
2023-12-12T15:56:24.430000Z	-17.394	126.042	6.831	4.2
2024-02-27T14:59:53.630000Z	-18.704	123.407	1.379	2.3
2024-03-19T08:23:52.450000Z	-18.371	123.898	4.263	2.4
2024-06-03T21:04:53.120000Z	-17.368	124.029	9.522	2.4

Table 1: List of the detected and located events between July 2023 and July 2024 in this project.

Yearly Seismicity (2010-2020)

We re-examined the historical earthquake catalogue from Geoscience Australia (GA) for 2010–2020 prior to the installation of the stations (Figures 7-9). As expected, the number of recorded events is low, which likely reflects limited detection capability due to sparse station coverage.

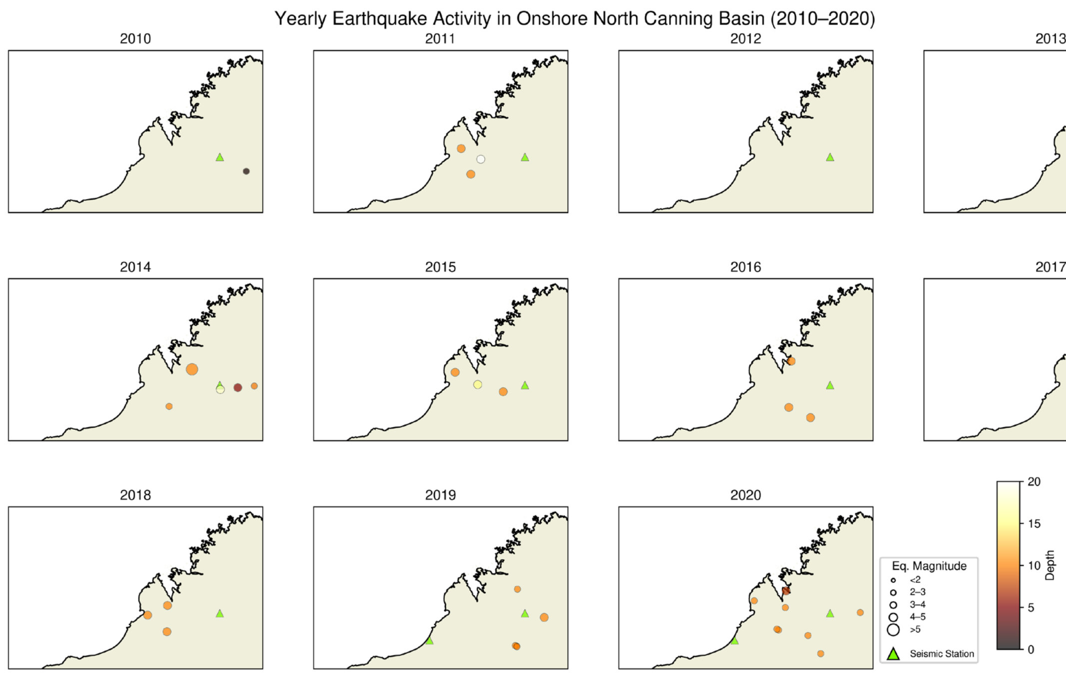

Figure 7: Yearly seismicity from 2010–2020 detected by the GA network. Green triangles show the seismic stations, with only one station operating between 2010 and 2018 and another one added later. Note that the plots do not include the offshore earthquakes.

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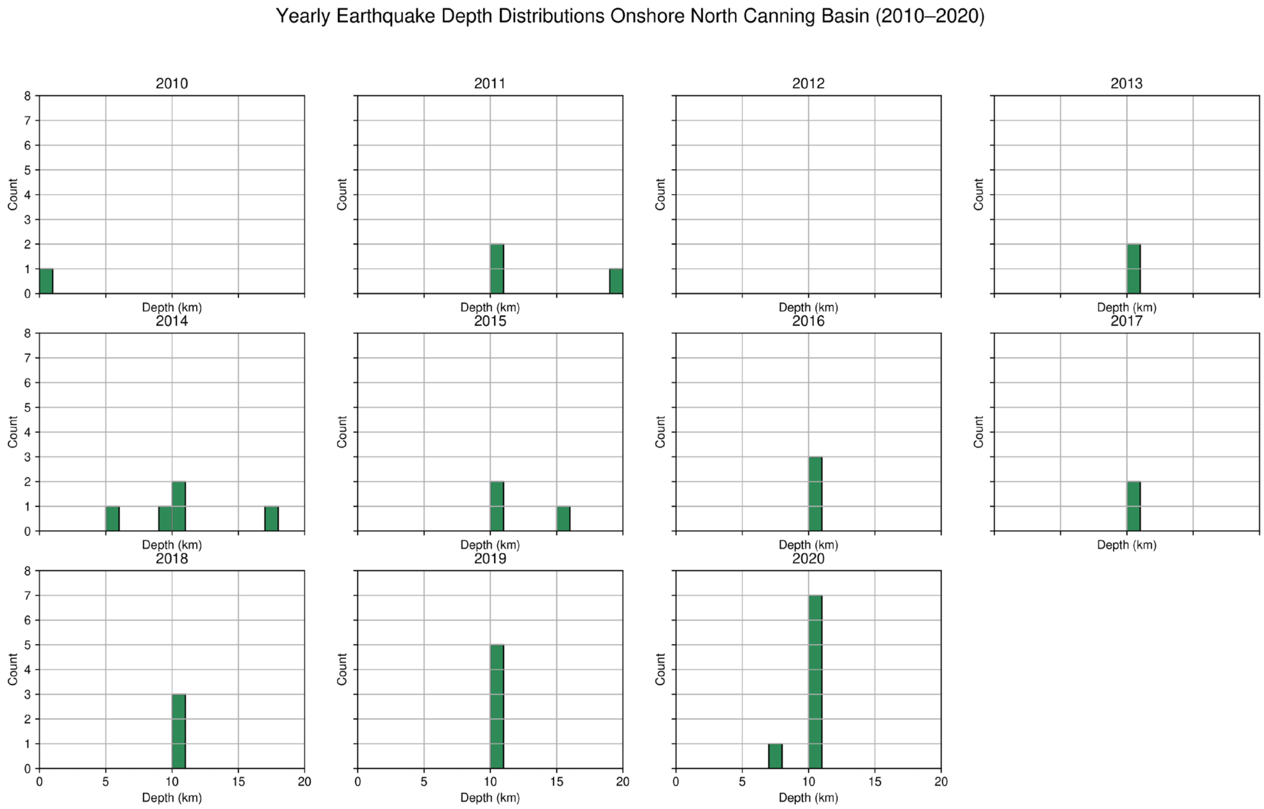

Figure 8: Depth seismograms for 2010 – 2020 seismic events. Note that the plots do not include the offshore earthquakes.

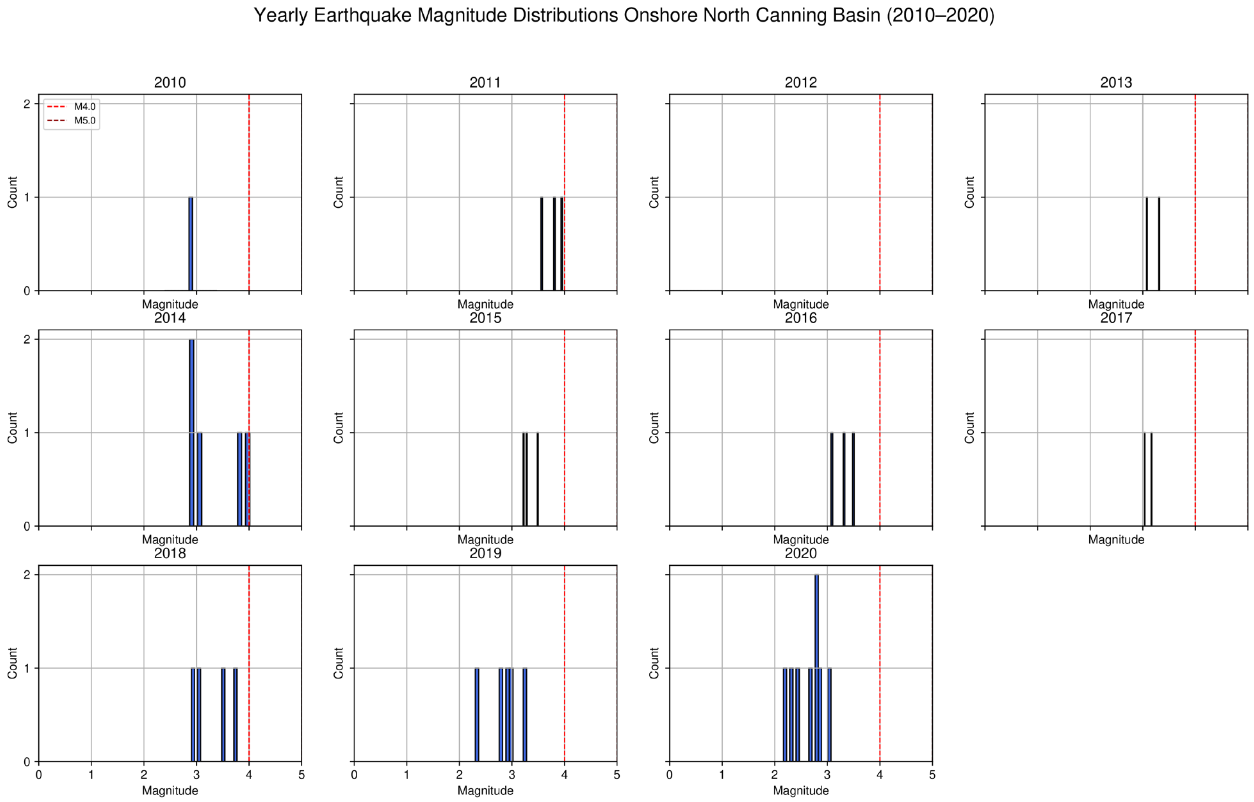

Figure 9: Magnitude distribution for 2010-2020 seismic events. Note that the plots do not include the offshore earthquakes. Vertical red line marks the magnitude 4 events.

Comparison with Geoscience Australia Catalogue

We compared the CSIRO catalogue with GA's for the same period and area. The catalogues show high spatial overlap. However, event depth estimates diverge substantially.

GA often reports depths clustered at 10 km, which is a default assignment when depth is poorly constrained. CSIRO's depth estimates are based on the continent-specific seismic velocity model developed by Chen et al. (2023) for Vs and AusRem (Salmon et al. 2013) for Vp, leading to reduced uncertainty and a more realistic distribution compared to GA's standard default-depth assignments

GA's standard workflow is based on deterministic detection algorithms. This is mainly due to the operational requirements, where ML based methods can be significantly more computationally intensive and time-consuming. Meanwhile, ML based methods are proven to be much more robust in other studies (Zhu & Beroza, 2019; Mousavi et al., 2020). In Figure 10, we show earthquakes from CSIRO and GA catalogues. Overall, the catalogues have a significant amount of similarity in the detected events (CSIRO: 9 and GA: 7) and general spatial locations. However, the depth distribution of the events for the catalogues have striking differences. The depth estimations from CSIRO used the velocity model of Chen et al. (2023) and AusREM (Salmon et al. 2013), which are specific for Australia resulted in lower uncertainty in depth estimates.

Here in our approach, we have better estimates of the depth which has a wider –range, whereas several of the GA depths are around 10 km, which denotes higher uncertainty. Geoscience Australia commonly assigns a default depth of 10 km in the absence of well-constrained solutions, which may contribute to the clustering of reported depths like the other agencies (USGS).

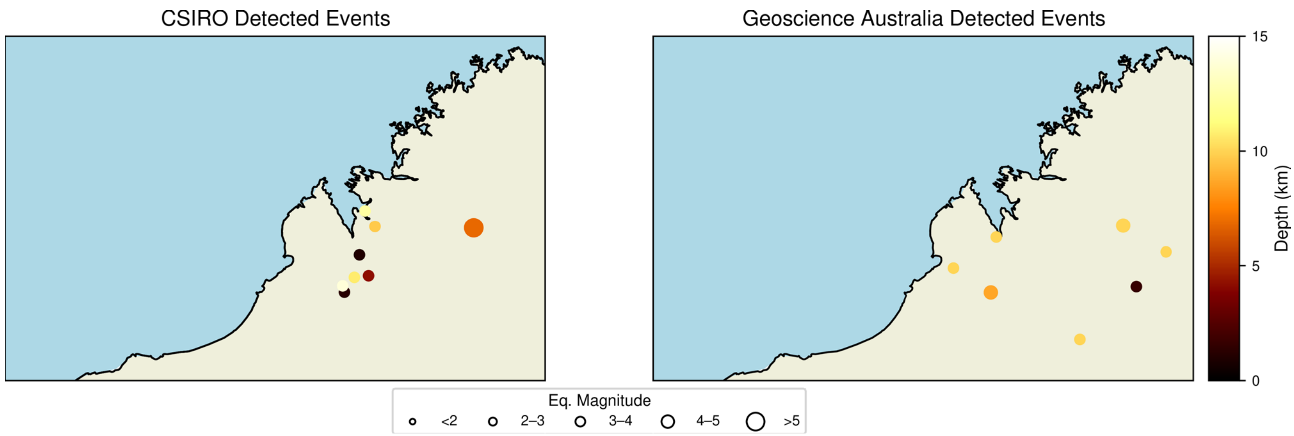

Figure 10: Detected events by this project and Geoscience Australia's catalogue for the same time period (2023-2024) and geographic area. Most of the earthquake depths of Geoscience Australia are around 10 km indicating high uncertainty as also seen in reported depths from other agencies, CSIRO's catalogue exhibits greater depth variation with most of them close to the surface.

Conclusion

The newly deployed GSWA stations have improved regional detection capability since 2021.Hence the number of detected events has increased accordingly. CSIRO and GA catalogues generally agree in event location, but CSIRO's depth estimates are more robust due to use of a continent-wide CSIRO crustal seismic model (Chen et al., 2023). Overall, we argue that there is no observable seismic activity increase during the analysis period.

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