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The Jamestown Earthquake M4.2 17th April 2024

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Abstract

A sequence of earthquakes, beginning on January 15th 2024, occurred close to Jamestown, South Australia. The largest earthquake caused widespread minor damage around the town. The next day an aftershock survey was initiated. About 100 events from the following week were manually processed, using a modified velocity model. The results indicate a shallow, near vertical rupture, striking north-west, and dipping towards the town. Given the limited number of recorders, careful processing was required. A focal mechanism was also produced with some similarity to the rupture plane, suggesting sinistral movement. No matching geological or geophysical feature was found.

Keywords: Aftershock deployment, focal mechanism, rupture, damage.

1 Introduction

Jamestown (population 1,500) sits in the mid-north of South Australia, within the main Mount Lofty – Flinders Ranges earthquake zone (Figure 1). While most earthquakes in the zone are independent events, larger events (M>3.5) usually have a few aftershocks, and occasionally earthquake sequences occur. Being about 200km north of Adelaide, it is feasible to visit and install multiple instruments within a single day.

The sequence began on 15th January with a magnitude 3.7 event and a number of aftershocks. The AUJCS station running at the Jamestown Community School recorded the event well, enabling a good location about 2-3 km to the NNE of the town. While the record was upset by digital filtering, the first break also indicated the NNE direction. This was a key component in planning the April aftershock survey. Three other events were recorded nearby in February and March.

The mainshock occurred at 0636 UT (4:06 pm local time) on Wednesday, 17th April. Many felt reports from the surrounding 50 km area were immediately displayed on the Geoscience Australia (GA) website, with a few as far south as Adelaide. The two authors conferred and decided that we could mount a survey the next morning with five aftershock kits. The mainshock was carefully located, without the Jamestown station which was not running. The epicentre was about 4 km NE of town, slightly east of the January event. These epicentres were both closer to town than the GA epicentres (Figure 2).

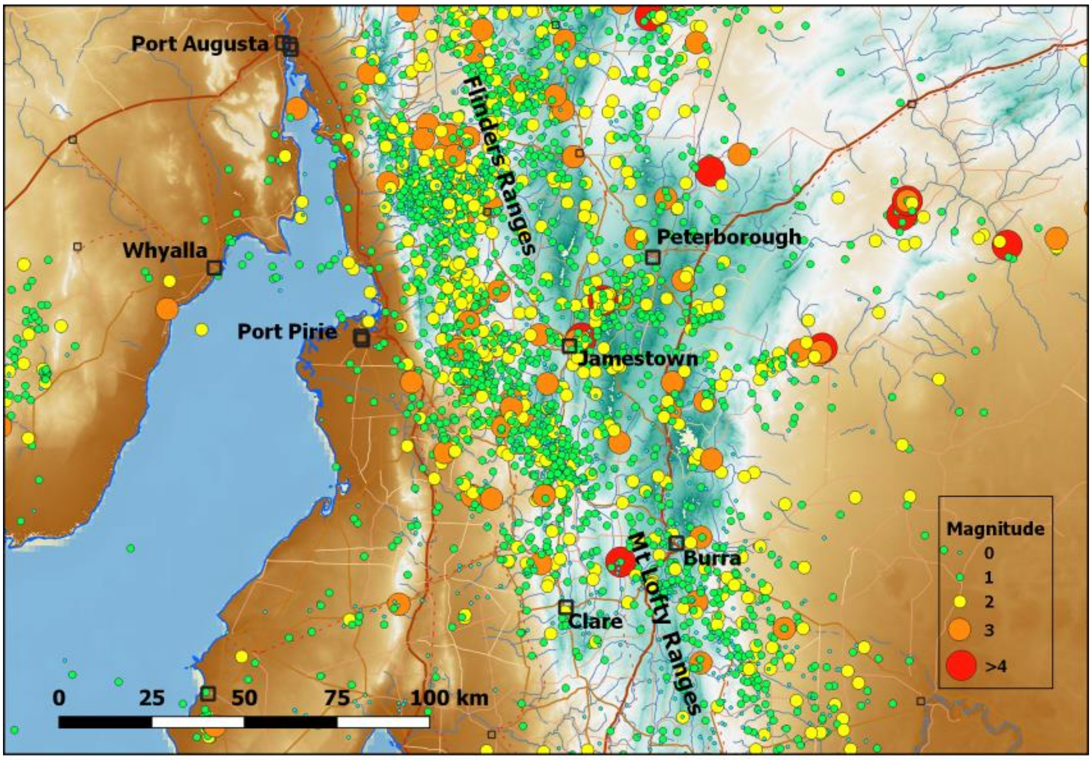


Figure 1. Regional seismicity since 2000 and elevation.

2 Portable deployment

We left Adelaide the next morning without any local contacts. The local police station was found unattended. We drove to the first house north of town and received assistance with contacts in the surrounding area. Four instruments were installed (Figure 2). All instruments were EchoPro recorders, running at 250sps with no filtering. JMS4 was installed first with a Guralp CMG5T accelerometer. The others had varying 1Hz 3D seismometers. A fifth instrument failed due to problems with a new LiFePO4 battery and regulator. Three units were powered by solar, with the fourth being solar plus mains. This unit had problems, and stopped recording after 11 days. It also had significant 50 Hz noise which caused problems picking P arrivals on smaller events.

In the following week a number of aftershocks were located, with many felt reports received by GA. One concerning feature was that the most common site for felt reports was a few kilometres to the NW of town, not within the portable network (Figure 2).

On 22nd May, a second trip was planned. Firstly, each instrument was visited to download data. Over lunch at the bakery four events were located. It was clear that they were well inside the network. The decision was made to finish the survey and pull the equipment out. A short visit was made to see some damage, then the equipment pulled out, residents thanked, and we returned home.

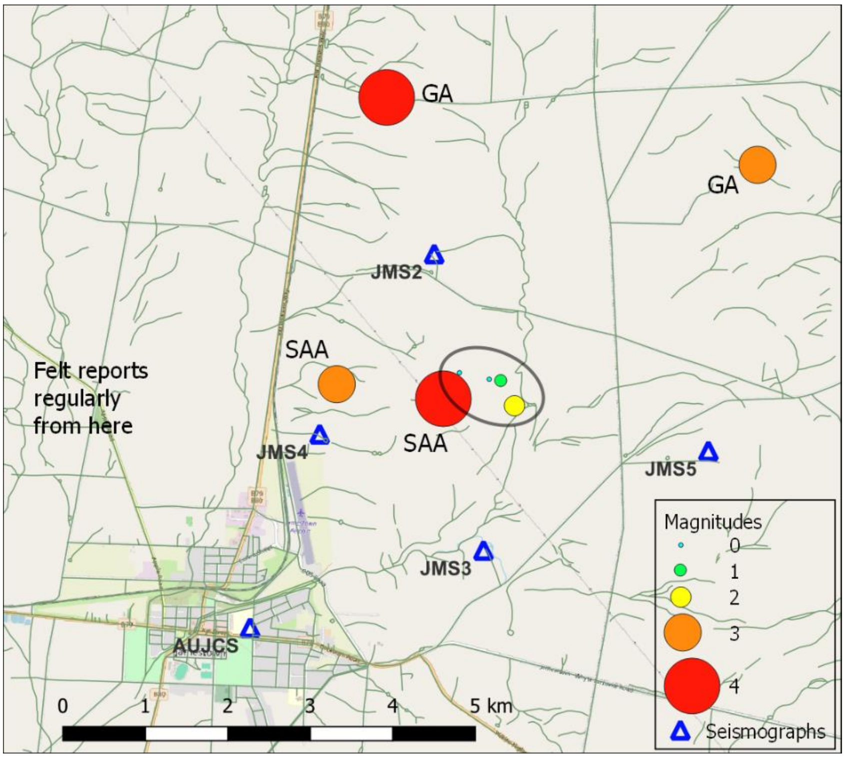


Figure 2. GA and SAA locations of the foreshock in January (ML3.7, orange circles) and mainshock in April (red circles). Locations of school seismograph (AUJCS) and portables are marked, as is the place where most aftershock felt reports were received. Locations of aftershocks calculated during pick-up trip shown by ellipse.

3 Processing

All event data is available at an SAA website (Love, E 2024). 104 events from 18th to 28th April were processed. Beyond this date JMS2 was not working, meaning that epicentres would be outside the network (gap >180°) with considerably lowered accuracy. Firstly the SA1A model (Parham, 1981) was used for 60 events. Model SA1A (Vp 6.23, Vs 3.58 km/s) is a single layer over Moho, based on deep rock velocities. The median standard deviation of residuals was 0.025 sec. Using these event locations and origin times, travel times were analysed and P and S velocities adjusted to reduce residuals. This resulted in model SAJ1(Vp 5.61, Vs 3.14 km/s) Events were then recalculated resulting in the median standard deviation of residuals dropping to 0.008 sec. Less accurate locations were removed.

In most cases, P arrivals were easy to pick with good signal to noise ratio, except for small events, and on JMS2 where 50Hz noise sometimes interfered.

S arrivals were often difficult to pick, or when they appeared to be clear, were clearly wrong. An example of this is in figure 3. There were no indications that the recorders drifted off time. Assuming they are correctly timed, the S arrival of the second seismogram (JMS5) must be earlier, and the S arrival of the fourth seismogram (JMS2) must be later, even though the S arrivals look clear. This was a puzzle, but it seems in general, the azimuths to the stations were usually close to the S minimum. Along nodal planes, the amplitude of S waves is usually greatest. Figure 7 indicates that often the direction of the wave was near a 45° angle to the nodal plane where the S phase was expected to be a minimum. Thus the arrival picked may have been a reflected P wave or converted wave. There were insufficient seismographs to investigate alternate theories.

Often the S arrival was picked from the integrated waveform (displacement for seismometers), with a 1 to 80 Hz bandpass. This emphasises lower frequency. Station AUJCS was usually left out, as the lower sample rate and digital filtering usually made arrivals much less certain. Without AUJCS, there was a maximum of 8 arrivals available to resolve 4 unknowns, not leaving much redundancy. In a similar, previous study (Love, D 2012), I had recommended a sample rate of 500. Our sample rate of 250 was adequate, but a higher rate may have been beneficial in trying to pick S arrivals.

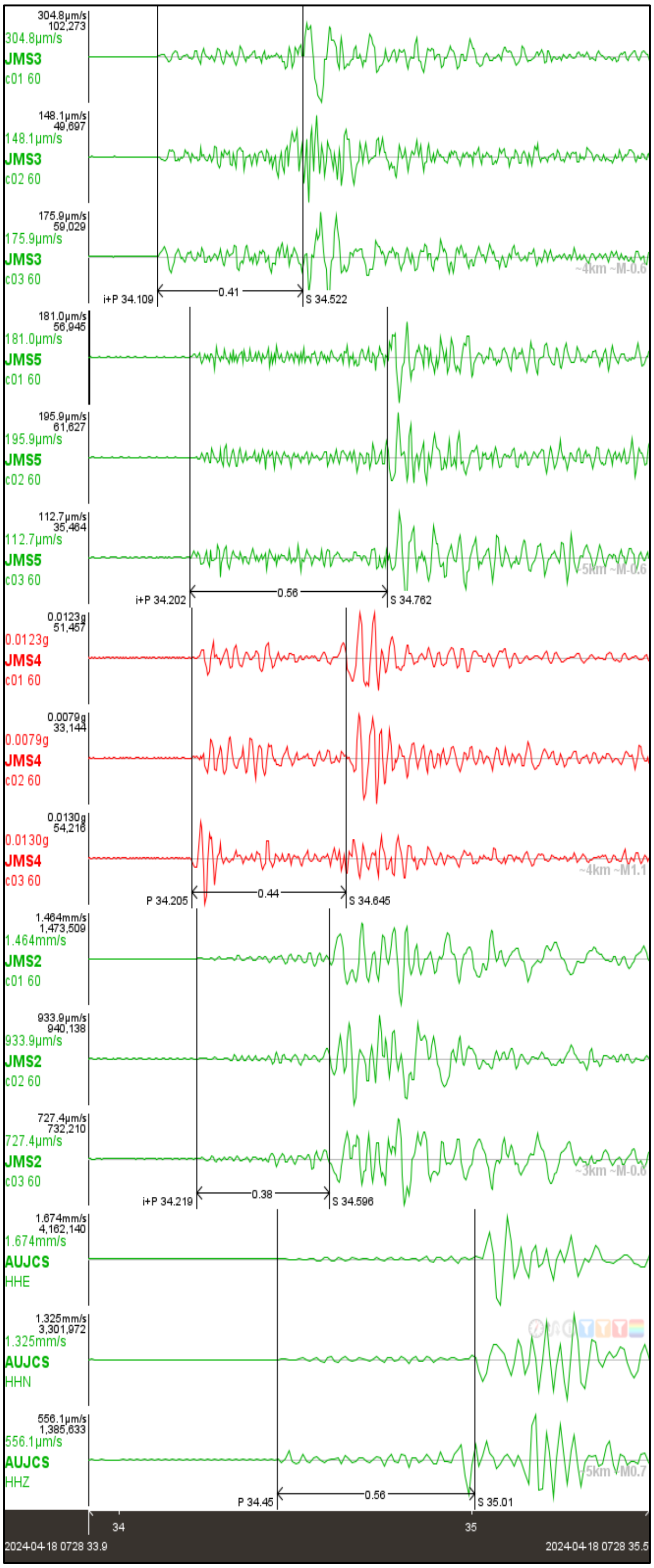


Figure 3. Example seismogram. There is clearly a problem. Either timing is incorrect (considered very unlikely) or the moderately clear S arrivals of the second and fourth stations must both be wrong.

4 Depths

In the first round of processing using velocity model SA1A, depths mostly ranged from 1.4 to 2.5 km. With the revised model SAJ1 depths mostly ranged from 0.7 to 1.7 km. As the nearest station was typically 1.8 km away, the shallower depths could not be considered reliable. The hypocentres had typical standard deviations of 30 m in the horizontal plan and 125 m in depth. It is possible that 6 or 7 sites with only a vertical sensor and reliable P arrivals would have produced better results than 4 sites with three axis sensor and reliable P but uncertain S arrivals! A critical factor in this is to have at least one recorder on top of the activity.

The best epicentres are plotted in figure 4. By rotating these in a spreadsheet, a main shock rupture strike of about 130°was estimated. A cross-section in figure 5 suggests a steep dip to the SW of 70 to 75°. This strongly suggests a strike-slip mechanism, not a thrust, therefore Insar was likely to show no elevation change. If the top of rupture was 0.7 km deep, then it is probable that any surface displacement might have been too small to be detected by Insar. Sotiris Valkaniotis (Democritus University of Thrace, Xanthi, Greece) kindly analysed the available data for an Insar response, and found nothing.

The rupture area, assumed from the aftershocks, is very roughly 1 sq km. The north western end is well defined, but the south eastern end is not.

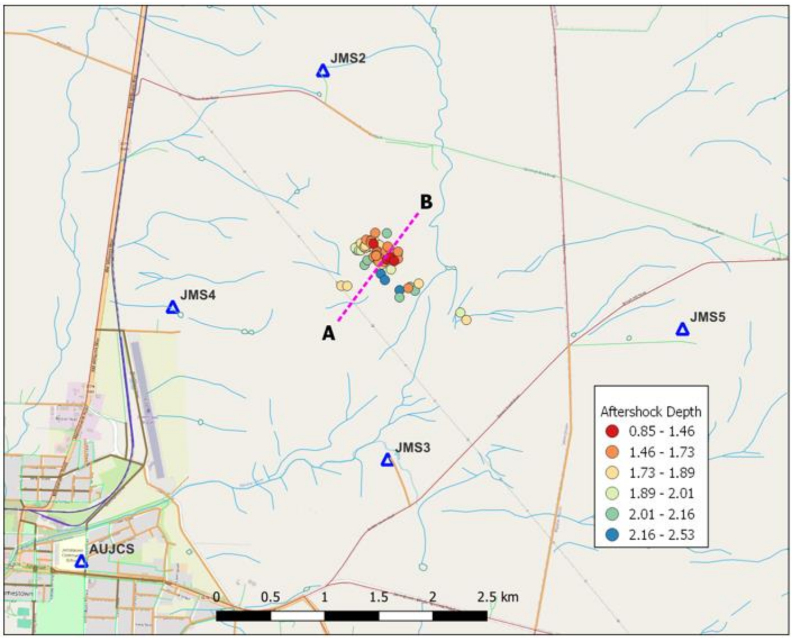


Figure 4. Aftershocks (revised velocity model, 8+ phases) coloured by depth.

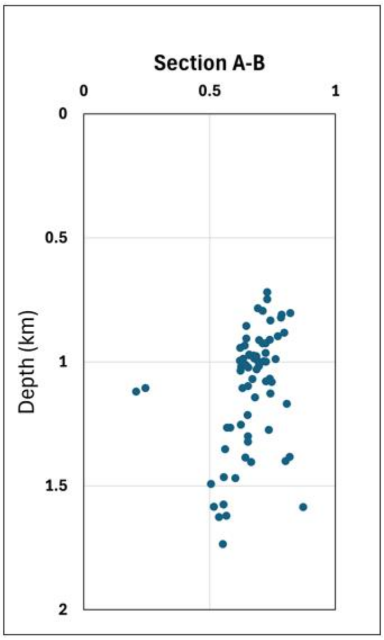


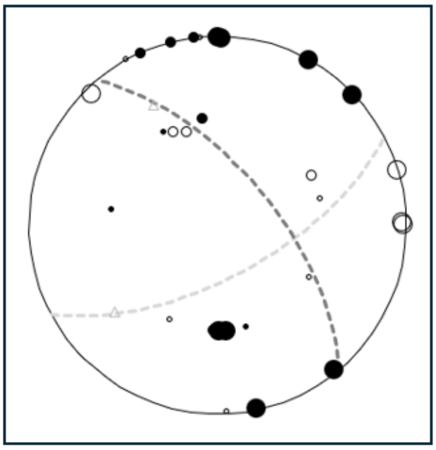
Figure 5 Cross-section A-B from previous figure showing depth

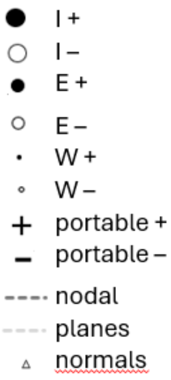
Earthquake depths in the Flinders Ranges extend from surface to about 30 km (Cummins et al 2004, Balfour et al 2015), which is possibly deeper than most other active areas of Australia. Shallower events require much closer spacing of seismographs to demonstrate the true depth of activity, and this is rarely done in Australia. Thus the percentage of very shallow events in the Flinders Ranges is unknown.

5 Focal mechanism

A first motion focal mechanism for the mainshock was produced using the SA1A model. This is not a realistic model for a shallow event, as nearly all arrivals fall either close to 0 degrees (outer circle) or the refraction circle, however we do not have another velocity model in general use in South Australia. (The modified SAJ1 model has no information below 3 km, therefore is not suitable either.) The mechanism included arrivals from 34 stations, however 11 of these were poor, and are shown as W in figure 6. A number of arrivals at the Alice Springs array were stacked, and likewise the Warramunga array, to produce two extra points in the diagram. Of the nodal planes plotted, the darker one roughly matches the strike of the indicated rupture plane from aftershocks, however the dip is in the opposite direction. This solution correctly fits all the I and E arrivals labelled I or E.

First motions of aftershocks on the four portables and AUJCS were fairly consistent. These have been added in figure 7 and are shown as + and -. If one ignores the stacked results from the two arrays, then the nodal planes can be plotted as a strike-slip (sinistral) mechanism. Since there are no seismographs close to the epicentre, there is some flexibility in dips on the planes. Both mechanisms show compression in the E-W direction.





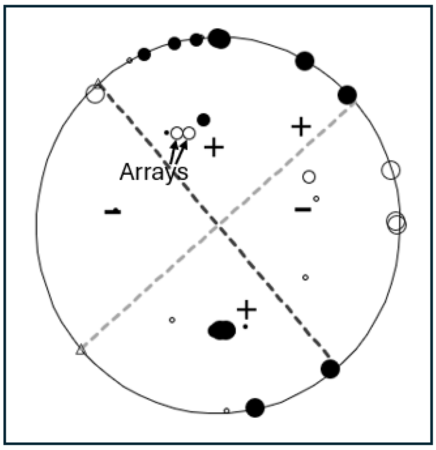


Figure 6. First motion focal mechanism, lower hemisphere.

Figure 7. First motion focal mechanism, including first motions on portables as + and -. Array results do not fit.

This E-W compression conforms well with Balfour et al (2015) who show that the principal stress regime in the Flinders Ranges is compression in a WNW-ESE direction for both shallow and deep events. Thrust mechanisms are the most common, although some strike slip cases are also found in the region around Jamestown. Cummins et al (2004) even showed one normal mechanism for a magnitude 3.9 event, the largest for that year.

6 Strong motion and effects

The strongest acceleration recorded was 0.20g at about 25Hz for a magnitude 3.0 aftershock at 2024-05-01 0110 UT on recorder JMS4.

Felt reports to the GA website suggested an intensity of about MM VI in Jamestown for the mainshock (Geoscience Australia, 2024). While in town, we heard of goods falling from shelves in a hardware store and a chemist. We heard of cases of slight building damage, and viewed one building with extensive low level cracking in masonry. This suggests that a magnitude increase of 0.5 could have been a major problem for the town.

7 Geology, geophysics and other activity

This earthquake occurred within the Adelaide Geosyncline, a complex of rifts and sag basins of Neoproterozoic metasedimentary rocks. These rocks has a strong north-south structural trend near Jamestown, dipping steeply to the east (Figure 8). The Wilyerpa Siltstone and Appila Tillite form a low range of hills through the region. The earthquakes are probably occurring in the Wilyerpa or Tapley Hill Formation. Uncultivated areas suggest that bedrock is not likely to be deep, but little exposed rock is not obvious in satellite images. The area around site JMS3 had some outcropping rock. No significant faults are marked in the region, however given some regolith cover and agricultural land use, this is not surprising. The Appila Tillite has a moderate magnetic response (Figure 9), and is the most significant feature in the region. Thus there seems to be no obvious geophysical or geological explanation for the rupture. The direction of compression, however, matches the structural trend of the ranges very well. Love et al (2006) noted that while there appeared to be some features in earthquake hypocentre maps of the Flinders Ranges (clusters and curvi-linear features), these did not appear to be associated with faults, folds or topography.

In 2011, a magnitude 4.1 event occurred near Yongala (Love, 2012), 12 km NNE of this event (see figure 1). Aftershocks were about 5 km deep, and appeared to be strike-slip with a similar east-west compression direction.

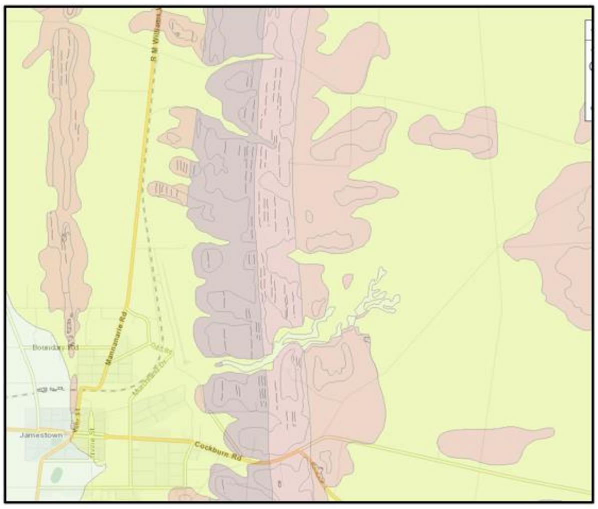


Figure 8 Surface geology from SARIG (2024)

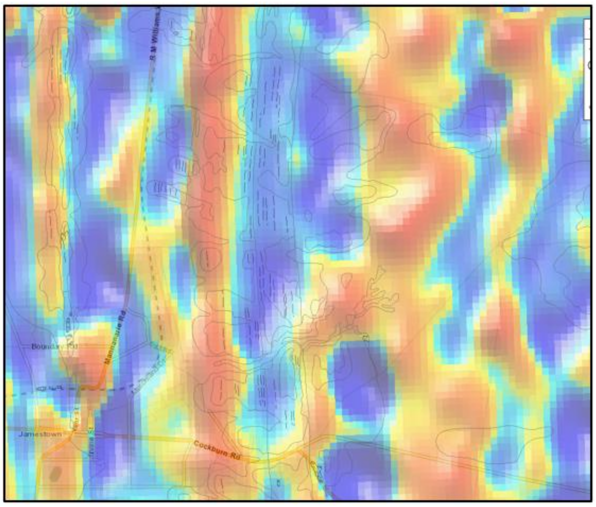


Figure 9. Magnetic intensity, vertical reduced to pole from SARIG(2024).

8 Discussion and conclusions

The rapid deployment and fortunate placement of seismographs in this survey resulted in a moderately successful outcome. The low gap (maximum 135°) and closeness of portables (always less than 6.6 km, with nearest being 1.4 to 1.9 km) produced good hypocentres. Depths and locations have been accurate enough to delineate a rupture plane that is in reasonable agreement with the focal mechanism. The rupture area of approximately 1 sq km is also in agreement with the magnitude of 4.2. The top appeared to be less than 1 km below ground level. However the small number of seismographs meant that data redundancy was limited. Thus uncertainty in wave picks could not be clarified. A higher sample rate may also have improved phase picks. A comparison of the cross-sections of Attanayake et al. (2020) and Brenn et al. (2021) for the Petermann Ranges earthquake (Figure 10) shows the significant difference between accepting only accurate data and including all data. Similarly we suspect that the volumetric rupture proposed by Murdie et al.(2022) for the Arthur River M4.8 event is a result of not removing poor quality data. No AI was used in our processing. Our results are not as clear as the near textbook case of a M4.1 event at Eugowra (Gibson et al, 1994), where many more recorders were used, resulting in high quality data.

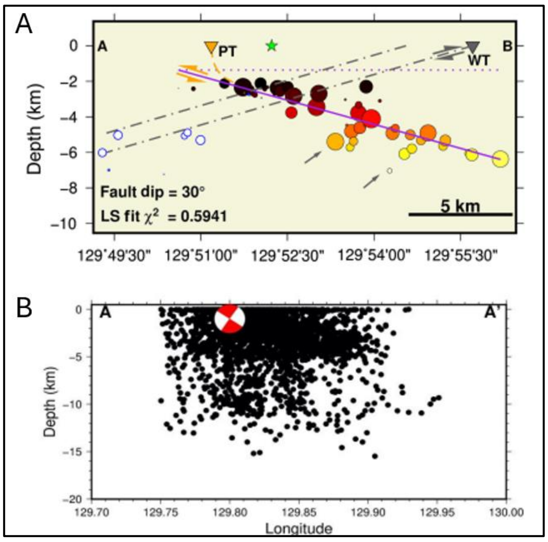


Figure 10. Comparing cross-sections of Attanayake et al.(2020) using only best hypocentres, and Brenn et al (2021) using all hypocentres.

The combination of aftershock locations, focal mechanism and the lack of Insar response all point to this being a strike-slip event. There is no evidence of any significant feature matching the proposed fault in the terrain elevation, geology or magnetics.

A larger number of recorders at higher sample rates would have made processing more straightforward, allowing for removal of any suspect S waves, leading to a clearer delineation of the rupture surface. While the SAJ1 velocity model reduced residuals markedly, the range of epicentral distances to the portables was quite limited. An improved velocity model would have been easier to validate with a wider range of epicentral distances. More recorders may have produced more focal mechanisms for individual aftershocks as happened in the Yongala survey (Love, 2011).

9 References

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