2015 Fraser Island Earthquake Sequence

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Abstract

On Thursday 30th July 2015 a magnitude M_{Lv} 5.6 earthquake was recorded approximately 100 kilometres east of Fraser Island, QLD, at 9:41am (local time). A magnitude M_{Lv} 5.4 aftershock was recorded on Saturday 1st August 2015 at 1:38pm followed by a magnitude M_{Lv} 5.2 aftershock just over an hour later. These earthquakes were all felt not only on Fraser Island but also on mainland Australia. A weak to light shaking was observed in a wide spatial area. The nearest seismograph to the event was approximately 205 kilometres away and the Seismology Research Centre (SRC) recorded over 90 aftershocks following the Fraser Island earthquake with magnitudes ranging from M_{Lv} 1.2 to 5.4.

This earthquake is one of the largest earthquakes to be recorded in Queensland; the largest in recorded history was the magnitude M_L 6.0 earthquake on the 6th of June 1918 located offshore north of Bundaberg. It is also worth noting that this is one of the few times an Australian state or territory has recorded more than four earthquakes above magnitude 5.0 in a single year; a magnitude M_{Lv} 5.2 earthquake was also recorded near Mount Perry, QLD, in February 2015.

Keywords: earthquake, Fraser Island,

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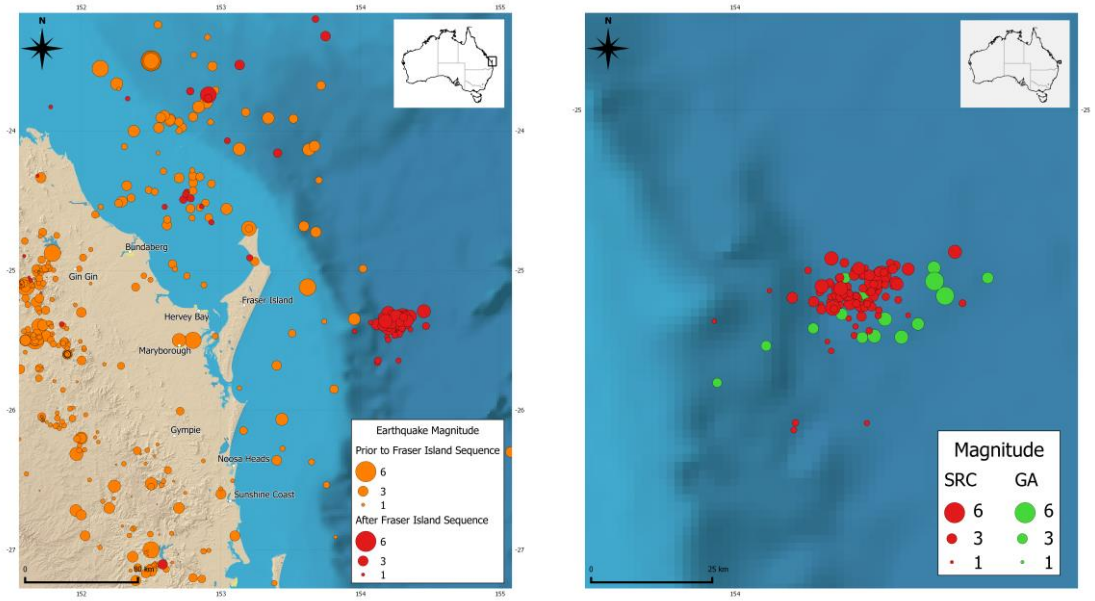
INTRODUCTION

The magnitude M_{Lv} 5.6 Off Fraser Island earthquake, recorded on Thursday 30th July 2015 at 9:41am (local time), was one of the largest earthquakes to be recorded in Queensland. The largest known Queensland earthquake is the magnitude M_L 6.0 event on 6th of June 1918 located offshore north of Bundaberg (Everingham *et al.*, 1982). Figure 1a shows the historical earthquakes in southeast Queensland together with earthquakes that were recorded after the M_{Lv} 5.6 Fraser Island event until the end of September 2016. Two relatively large events were recorded a couple of days after the mainshock; a magnitude M_{Lv} 5.4 aftershock on Saturday 1st August 2015 at 1:38pm, followed by a magnitude M_{Lv} 5.2 aftershock just over an hour later. To date 94 earthquakes have been recorded by the Seismology Research Centre (SRC) in this sequence of events (Figure 1b); the latest in the sequence being a magnitude MLv 2.0 on 11th August 2016. The clustered nature of the events is swarm-like; a long sequence of events has occurred but with no significant main event (Gibson 2004) as the two largest aftershocks are quite close in magnitude to the mainshock.



(a) (b)

Figure 1 (a) Historical seismicity in southeast Queensland prior to and after Fraser Island sequence up to end of September 2016 **(b)** Fraser Island earthquake sequence locations by SRC and GA

TECTONIC EVOLUTION OF EAST COAST OF AUSTRALIA

The breakup of the supercontinent, Gondwanaland, is the background for the tectonic evolution of Australia's continental passive margins. As the Australian, Antarctic and Pacific Plates broke apart, they gave rise to offshore seafloor spreading (Figure 2) since the Late Cretaceous period (80 Ma). The opening of the Tasman Sea propagating northwards from the Cato Trough and Coral Sea Basin occurred from the Palaeocene (65 Ma) with seafloor spreading ceasing by 55 Ma. This cessation coincides with seafloor spreading commencing between Antarctica and Australia soon after. The southern seafloor spreading marks the onset of marginal basin spreading behind the western Pacific island arcs, including New Hebrides Basin (Falvey & Mutter, 1981).

Figure 2 Reconstruction of Australian, Antarctic and Pacific Plates at 45 m.y. B.P (Falvey & Mutter, 1981)

The recent magnitude M_{Lv} 5.6 earthquake on July 29th 2015 and subsequent aftershocks off the east coast of Fraser Island may show evidence of re-awakening of these failed rift margins along the southern end of the Capricorn Basin (Figure 3) which is comprised of Cretaceous clastic sequences, considered to be rift-phase deposits (Taylor & Flavey, 1977). This basin is believed to be part of the continued northward propagation of seafloor spreading during the Palaeocene, observed along the Halifax Basin and further north to the Osprey Embayment. The unusual distribution of continental troughs along the northeast coast of Australia suggests at least three Mesozoic three-branch rift systems, with the Townsville and Queensland Troughs and the Osprey Embayment representing failed arms (Falvey & Mutter, 1981).

Further to the east of Fraser Island, the chain of volcanic islands are remnants of the Australian-Antarctic rifting as offshore development of a mid ocean ridge seafloor spreading centre. This Cretaceous volcanism was related to a minor episode of arc formation, typical of Queensland's Whitsunday Islands.

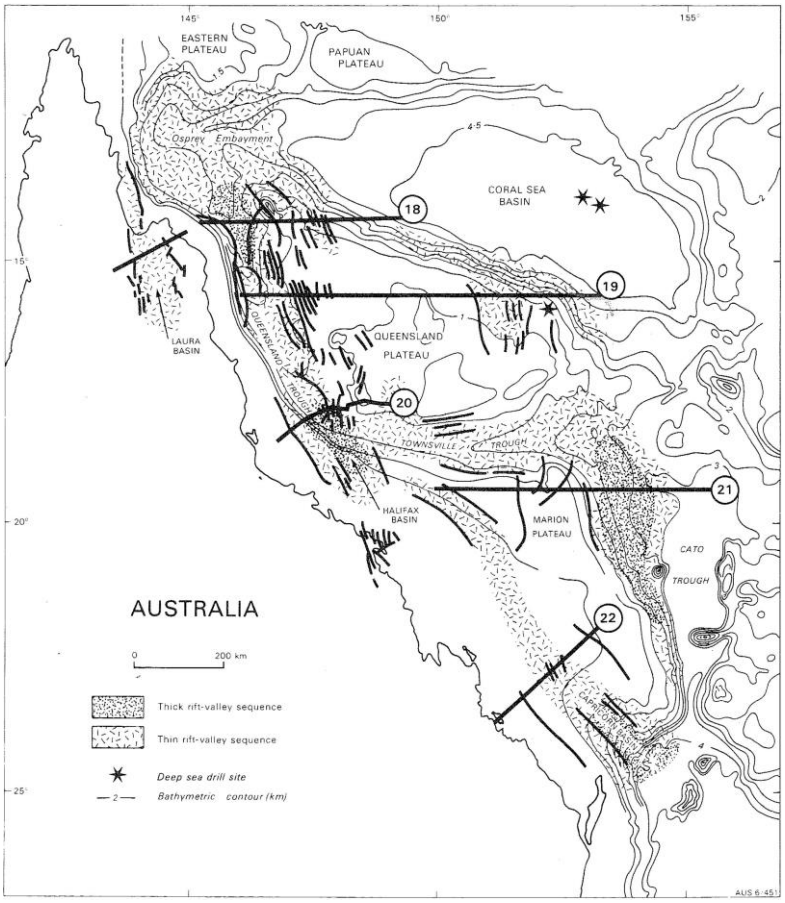


Figure 3 Bathymetry and principal structural and depositional patterns on the northeast margin of Australia (Falvey & Mutter, 1981)

MAINSHOCK AND SEQUENCE

The mainshock occurred at 9:41am (local time) on July 30th approximately 100 kilometres east of Fraser Island. As this event was already located about 100 kilometres offshore, the nearest seismic station to the event was more than 200 kilometres away. Magnitudes calculated by the SRC were generally similar to other agencies for the aftershocks however did differ slightly for the mainshock Table 1). This could be due to a range of reasons including the higher density of seismographs used in SRC solutions and distance to the seismic stations. SRC magnitudes for the mainshock ranged from M_{Lv} 5.3 to M_{Lv} 5.8. In the final solution twelve seismic stations were located within 300 kilometres of the mainshock; twenty-two seismic stations were located within 400 kilometres (Figure 4).

Table 1 Event parameters for the mainshock and two largest aftershocks*

Date/Time (UTC)	Latitude	Longitude	Depth (KM)	M_{Lv}	M_L	M_b	M_{wp}	M_{ww}
2015-07-29 2341	-25.3413	154.3021	10 (SRC) 13 (GA) 9 (US)	5.6 (SRC)	5.6 (SRC) 5.3 (GA)		5.4 (GA)	5.5 (US)
2015-08-01 0338	-25.3704	154.2967	10 (SRC) 13 (GA) 9 (US)	5.4 (SRC)	5.4 (SRC)		5.3 (GA)	5.4 (US)
2015-08-01 0446	-25.3550	154.2833	10 (SRC) 30 (GA) 10 (US)	5.2 (SRC)	5.1 (SRC)	5.1 (GA)		5.2 (US)

*SRC=Seismology Research Centre; GA=Geoscience Australia; US=USGS National Earthquake Information Centre, PDE

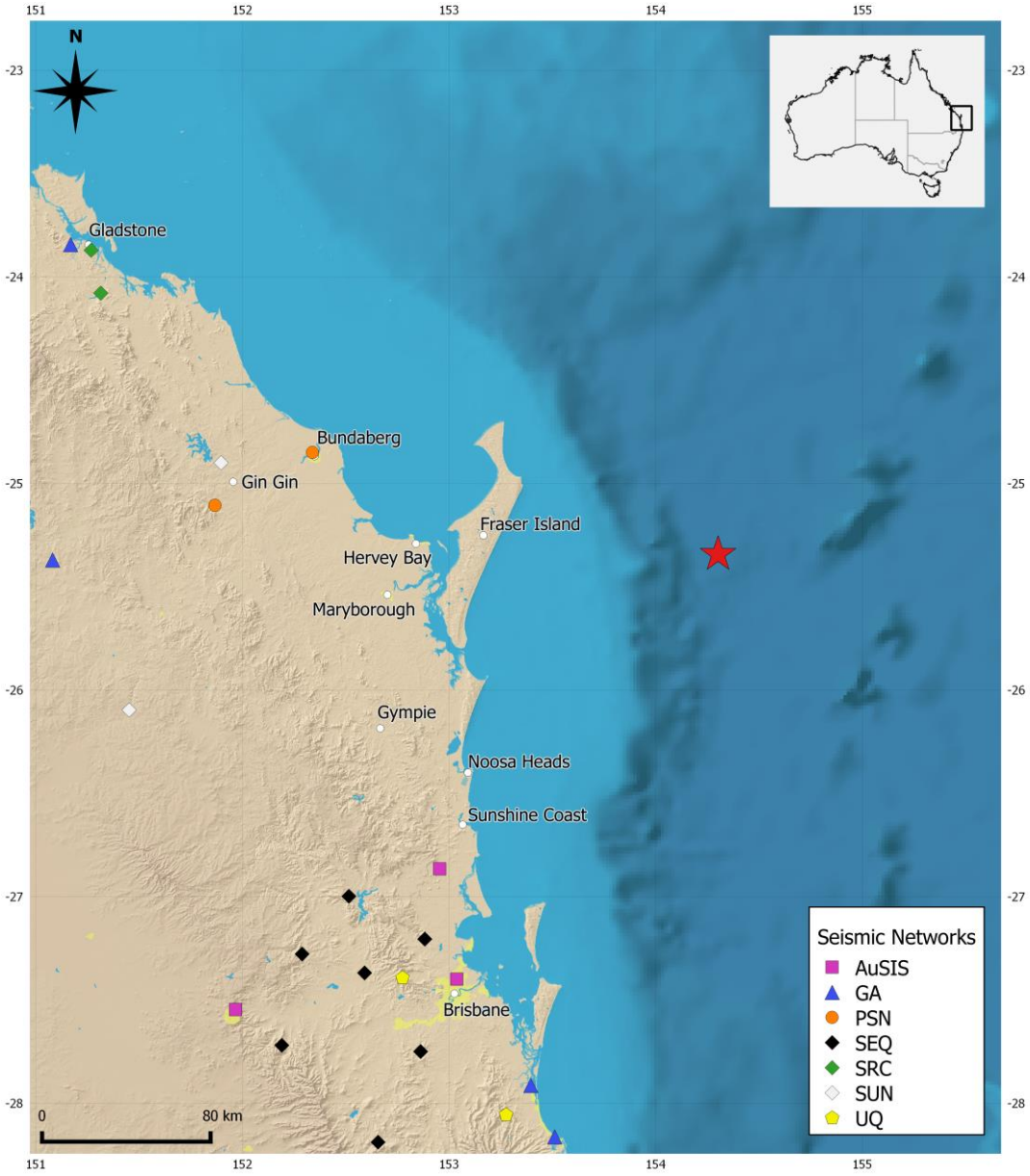


Figure 4 Mainshock epicentre relative to seismic networks (AuSIS=Australian Seismometers in Schools, GA=Geoscience Australia, PSN=Public Seismograph Network, SRC=Seismology Research Centre, UQ=University of Queensland)

The Public Seismograph Network (PSN) stations were invaluable to this sequence of events as they were two of the three closest stations to the mainshock. Seismologists from the SRC analysed all triggered recordings and also went through the continuous data from the closest two PSN stations in order to ensure as many aftershocks could be located as possible. The smallest event detected in the sequence was a magnitude M_{Lv} 1.4 earthquake (Figure 5). This earthquake was only just able to be made out over background noise level. Due to the thorough analysis of the continuous PSN data up until the end of 2015, it is believed every event over magnitude M_{Lv} 1.5 has been located. More aftershocks are likely to have occurred but were not detectable due to the distance of the earthquakes from the closest seismic station. Large gaps can also be seen in Figure 5 where the magnitude of each aftershock is shown over time. The large gaps between events indicate smaller events may have occurred but have not been detected.

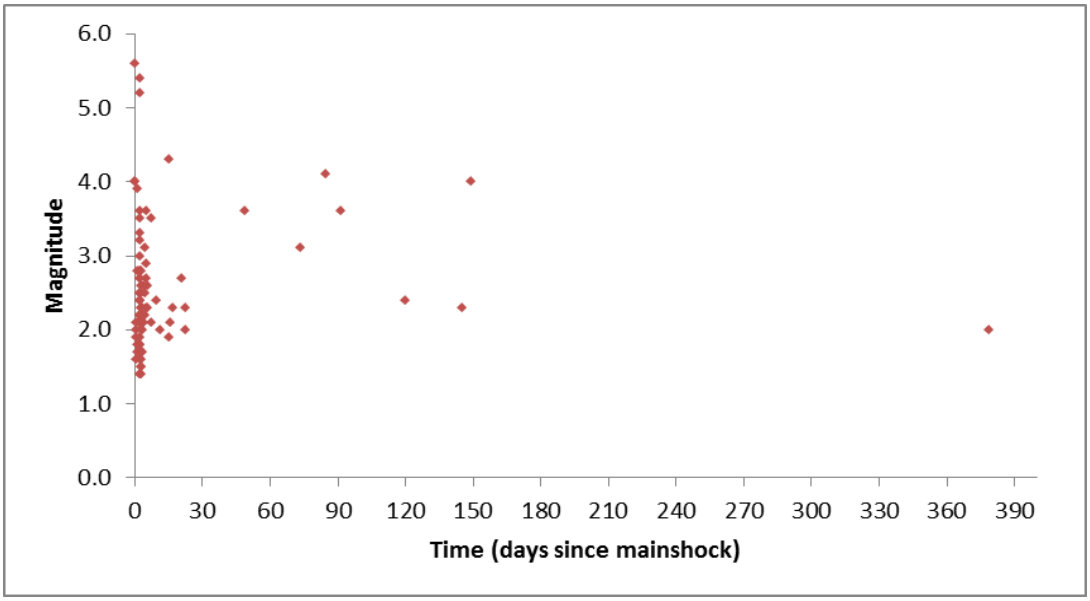


Figure 5 Magnitude of each earthquake in the Fraser Island sequence over time

Geoscience Australia's closest seismic station was approximately 300 kilometres away. GA's published database contained only locations above magnitude M_L 2.7. This may explain why the number of events in the first few days is significantly different to the SRC's (Figure 6).

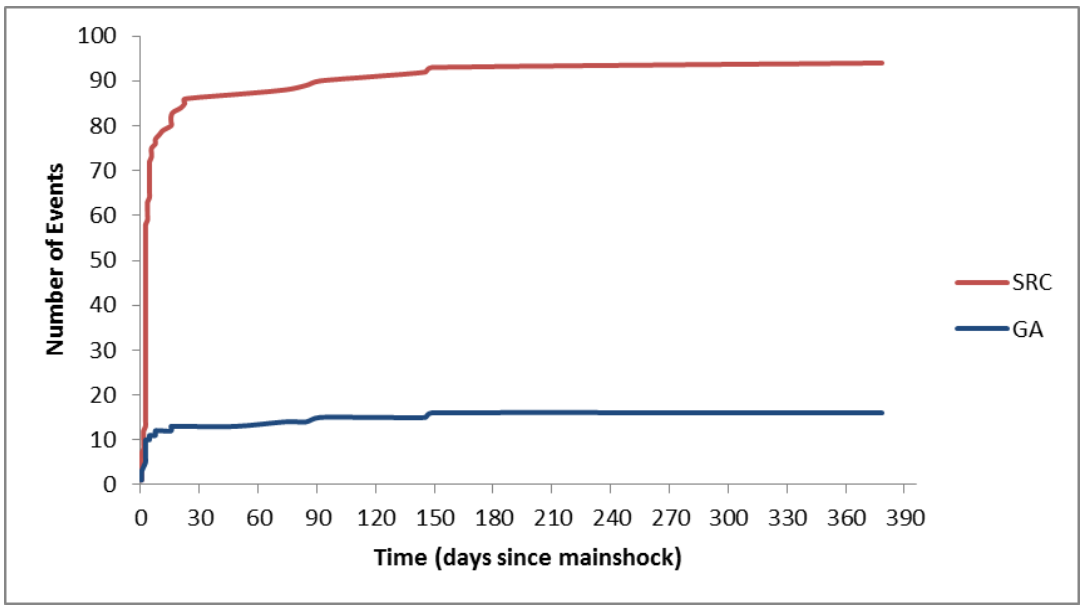
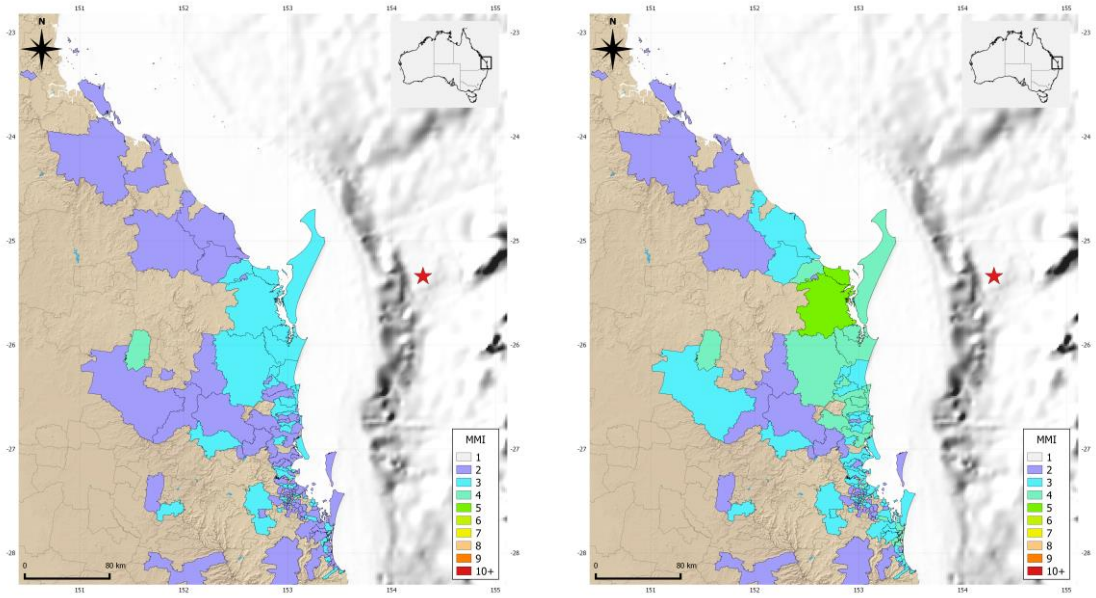


Figure 6 Cumulative numbers of observed aftershocks of the magnitude M_{Lv} 5.6 Off Fraser Island earthquake versus Time for the SRC and GA

FELT REPORTS

The SRC and GA combined received over 1,100 felt reports for the magnitude M_{Lv} 5.6 earthquake on July 29th 2015. The median Modified Mercalli Intensity (MMI) for each postcode was calculated (Figure 7a) and a weak to light shaking was shown to be felt over a wide spatial area. Many of the reports were from persons residing in "*Queenslander"* or "*pole"* style homes generally constructed from timber and elevated with an underfloor area used for ventilation. The felt reports associated with these types of construction were generally higher in intensity than others; possibly as most people were in elevated floors at the time of the event. Many of the maximum reported intensities came from these elevated homes and, for comparison,

Figure 7b shows the maximum reported intensity for each postcode and a moderate to light shaking is now observed.



(a) (b)

Figure 7 (a) The median Modifed Mercalli Intensity observed by postcode and **(b)** the maximum Modified Mercalli Intensity observed by postcode for the magnitude M_{Lv} 5.6 earthquake on July 29th

Intensity data gathered by the US Geological Survey 'Did you feel it?' reports (Wald *et al*., 2011) exhibited a very similar result for the mainshock of a weak to light shaking from only 41 responses.

ACCURACY

Details of the mainshock and two largest aftershocks are given in Table 2. Quoted uncertainties are as specified by the SRC developed earthquake location program *eqFocus* computed to two standard deviations. *eqFocus* was used to locate all events using the SEQ2A two dimensional local crustal model. The two Public Seismograph Network stations as well as the Australian Seismometers in Schools stations helped improve confidence in the calculated results.

Table 2 Uncertainties for the magnitude M_{Lv} 5.6 Off Fraser Island earthquake and the two largest aftershocks

Event	**Mainshock**	**Aftershock**	**Aftershock**
UT Date	2015-07-29	2015-08-01	2015-08-01
UT Time	2341	0338	0446
Magnitude	5.6	5.4	5.2
Latitude	-25.341±0.017°	-25.370±0.011°	-25.355±0.012°
Longitude	154.302±0.022°	154.297±0.015°	154.283±0.015°
Depth	10±2.2	10±1.3	10±1.6
Stations within 300km	12	12	12
Number of Arrivals Used	46	45	39
Gap Angle	241	255	255
SD of residuals	0.619	0.436	0.385

DISCUSSION

The Fraser Island sequence of 2015 recorded almost 90 events, three of which were over magnitude 5.0. Earlier in 2015 a magnitude M_{Lv} 5.2 earthquake was also

recorded in QLD near Mount Perry. This is one of the few times an Australian state or territory has recorded more than four earthquakes above magnitude 5.0 in a single year. Queensland frequently has small to moderate earthquakes especially in southeast Queensland. Events off Fraser Island, Gladstone and Bundaberg would benefit from an ocean bottom seismograph. This would help improve locations but also perhaps record more events and aftershocks in sequences that would otherwise go unrecorded. A magnitude M_{Lv} 4.7 earthquake was recorded as this paper was being finalised, approximately 135 kilometres east of Gladstone on August 14th 2016, highlighting the need for a station offshore. This was followed by a magnitude M_{Lv} 5.9 earthquake just four days later on August 18th, approximately 30 kilometres north of Hayman Island. This is the second largest earthquake in recorded history for Queensland.

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