Investigation of an earthquake cluster near Corrigin, southwestern Australia, July 2017

V.F. Dent[1] and A. J. Judge[2]

1. University Associate, Curtin University, Perth, WA.
   Email: vic_dent@yahoo.com
2. Martin Observatory, Frensham St., Martin, WA.

Abstract

A magnitude 3.3 earthquake north of Corrigin was followed by about 40 aftershocks, mainly in the first 12 hours of the sequence. GA locations suggest a zone about 20 km long, with a NW-SE trend. A field seismograph was deployed in the area three days after the sequence started, and moved a bit closer to the epicentres after a week. Five aftershocks were recorded, and the data used for relocations. Some of the earlier events have also been relocated, and the relocations suggest that all events may have originated from a location about 6 km ESE of the second recorder location. The focal depth is estimated at 3 km, +/- 2 km. A plot of historical events suggests that seismicity in 2000-2001 may have come from the same location.

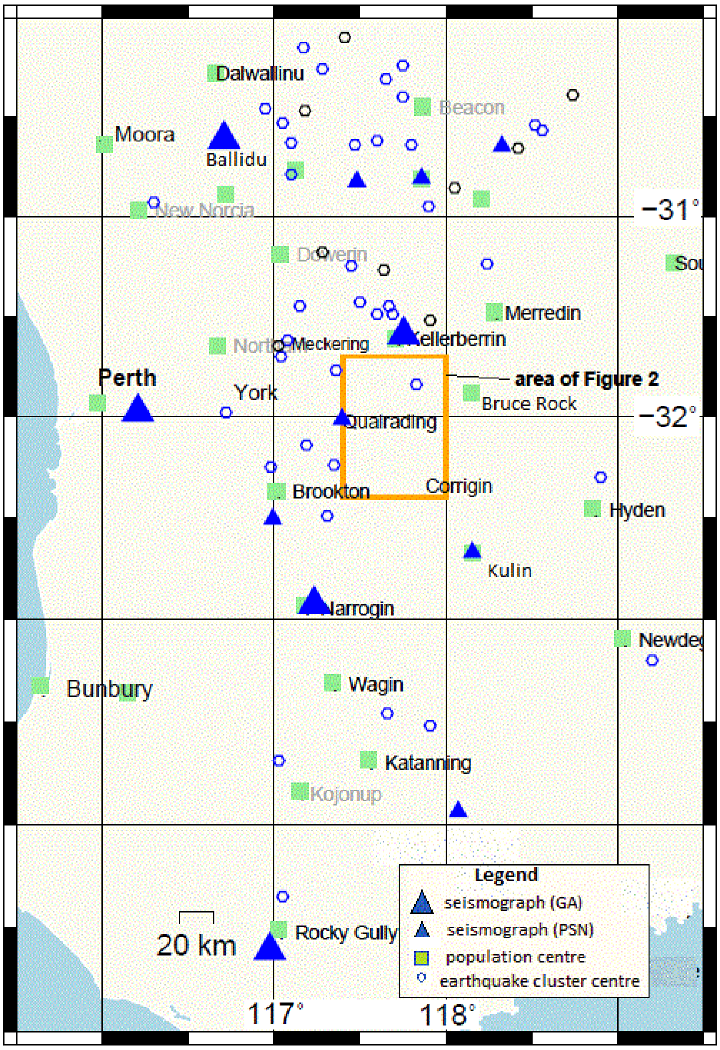
Keywords earthquake cluster, southwest Australia, recurring seismicity

1 Introduction.

Corrigin is a small town (population ~900) in the central wheat belt of WA, about 150 km east of Perth (Figure 1), and about 60 km southeast of the village of Meckering, which was destroyed by a magnitude Mw 6.5 earthquake in October 1968 (Gordon & Lewis, 1981). It is within the Southwest Australia (SWA) seismic zone defined by Leonard, (2008), a region of high level of seismicity relative to the overall low levels of the Australian continent. It is also within the smaller "southwest seismic zone", a name given by Doyle (1971) for a region of relatively high seismicity east of Perth identified by Everingham (1966).

The dominant expression of seismicity in the SWA region is as seismic clusters, and cluster centres which have been identified from recent seismicity (Dent 2017) are also shown on Figure 1.

Figure 1 Location map



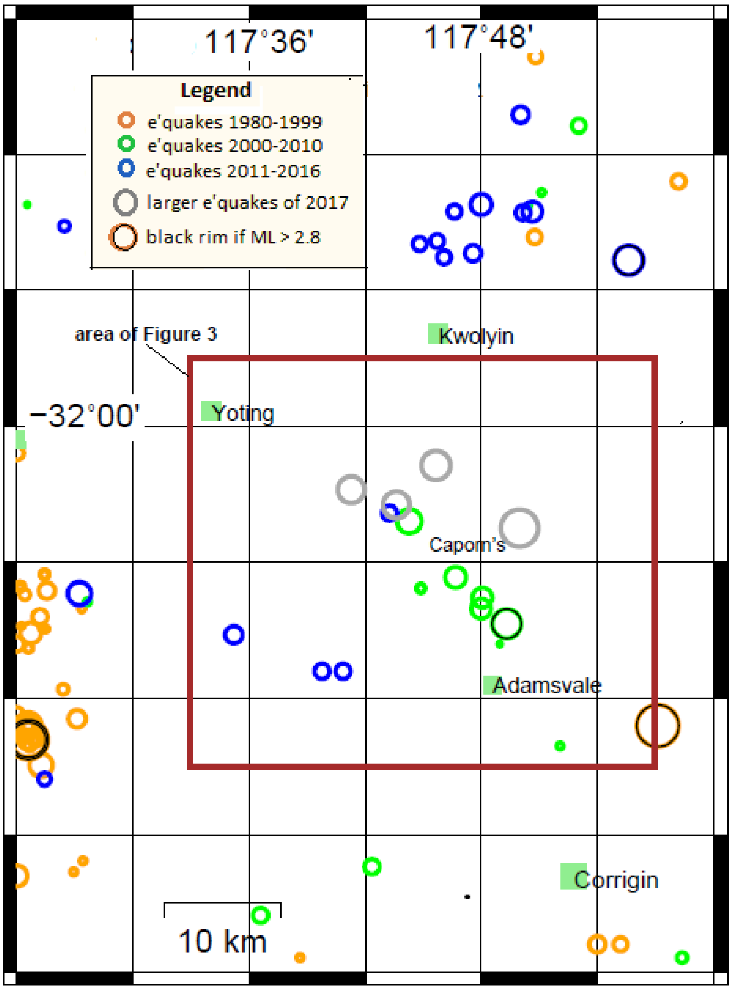
Geoscience Australia (GA) has 5 seismic stations in southwest Australia (Figure 1), which it relies on to locate earthquakes which occur in the region. Seismic monitoring in the region has been improving since 2006 with the development of the PSN network (Dent et al., 2009), and in July 2017, 8 stations were operating (Figure 1).

A magnitude 3.3 event at 1503 hrs GMT on 19th July, 2017 at a location ~ 30 km north of Corrigin was followed by about 40 aftershocks over the next three months, but most of these were within 3 days of the first event. A field instrument was deployed near the epicentre three days after the main event, as will be discussed below.

2 Historical seismicity (1980-2016)

Earthquakes 1980 – 2016 are plotted on Figure 2. This figure is colour-coded for three time periods, 1980 – 1999, 2000 – 2009, and 2010 – 2017. The most active period was in the 1980's, with a number of magnitude 3+ events, mostly about 30 km west of the 2017 activity. However, some of the locations on Figure 2, particularly the earlier ones, are considered of poor quality (location errors up to ~ +/- 20 km). Considering the possible location errors, it is possible that much of the activity in the 1980's came from a single cluster location, possibly cluster location F5, as defined in Dent (2017).

Figure 2 seismicity 1980 - 2016



During the period 2000 to early 2002, seismic activity moved close to the location of the 2017 activity. The largest in this period was ML 2.9, on 30th June 2001.

During July 2011, late 2013 and also in early 2014, seismic clusters were recorded north of the 2017 activity. The largest event in that period was ML 2.9 in Sept 2015 (called "Bruce Rock cluster", E2, in Dent 2017).

3 Seismic activity in 2017

A group of 41 aftershocks (to 15th October, 2017) followed a main shock (ML 3.3), on 19th July 2017, mostly within 12 hours of the main event (Figure 3). The biggest aftershock was ML 2.9 and there were also two ML 2.8 events, all within the first 12 hours. Only occasional events were recorded after July 22nd. The distribution of earthquakes vs. time is shown in

Figure 3 Earthquakes near Corrigin, 01/01/2017 to 31/10/2017

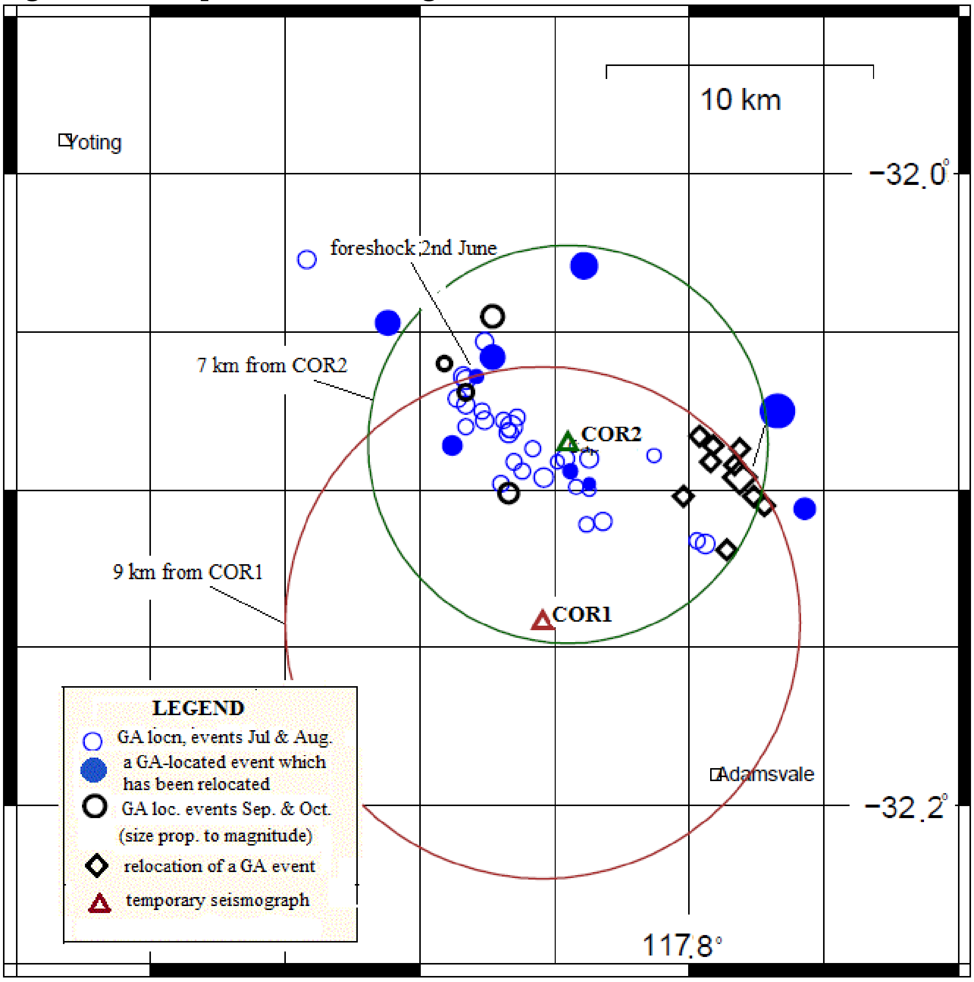
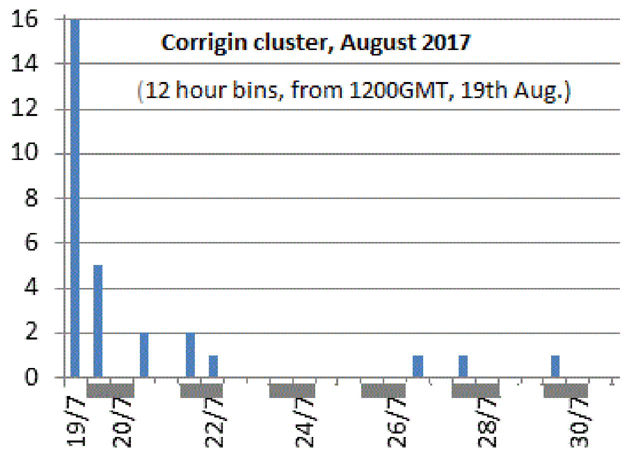


Figure 4. Examination of the GA catalogue shows that a small foreshock occurred on 2nd June, ML 2.1 (1734 GMT). GA has given all events a focal depth of 10 km.

4 Near-field monitoring by a field instrument

A field instrument was deployed in the area on 22nd July 2017 – 3 days after the main event. It was operated at location COR1 for a week at the farm of Robin McLeary (Figure 2). Their son had apparently noticed a tremor, but it was not noticed by others in the house. During the week it operated, the recorder recorded three aftershocks (largest ML 2.4**).** These all had S-P intervals of close to 1.0 seconds at the COR1 station (Table 1 and Figure 5).

Figure 4 Distribution of Corrigin events with time



After the seismograph had operated at McLeary's for a week it was moved about 7 km north, to Caporn's farm, (COR2). There it recorded several more aftershocks, with S-P times all about 0.8 secs (Table 1).

5 Relocations of events

The main shock and its aftershocks were recorded on the 8 operating stations of the PSN network, as shown on Figure 1. These stations, even without the additional data from the near field sites, have allowed relatively accurate relocations of the GA solutions to be made (Table 1). Of particular importance are stations at Quairading and Kulin (Figure 1), even though they are situated in the village centres, and have periods of high background noise. The limited data from the temporary stations (COR1 and COR2) are also very useful in the relocations. The relocations generally move the epicentres to the ESE, by distances of up to 12 km. They suggest the aftershocks are grouped around the corrected main-shock location (32.095^{o}S, 117.82^{o}E), about 6 km east-southeast of the COR2 seismograph.

Table 1 Table of relocated events, and events after the deployment of the field station

Date 2017	Time	relocation		ML	Dep km*	Comments	GA locn		Move (km)
	UTC	Latitude	Longit.				Latitude	Longit.	
02June	1734	-32.091	117.808	2.1	2C	foreshock	-32.064	117.721	9
19July	1505	-32.096	117.819	4.2	2C	Mainshock	-32.075	117.833	3
19July	1754	-32.087	117.819	2.9	2C		-32.029	117.761	8
19July	1835	-32.083	117.804	2.8	2C		-32.047	117.688	12
19July	2002	-32.102	117.798	2.8	2C		-32.058	117.727	8
20 July	1659	-32.086	117.809	2.6	0.9		-32.106	117.843	3
27July	1659	-32.092	117.817	2.2	2C	SP 1.1s. at COR1	-32.094	117.756	6
28July	1050	-32.102	117.824	2.4	2C	SP 1.1s. at COR1	-32.086	117.712	11
30July	0352	-32.105	117.828	2.3	2C	SP 1.0s. at COR1	-32.080	117.717	11
26Aug	1757	-32.119	117.814	1.9	2C	SP 0.75s. COR2	-32.098	117.763	6
23Sep	1941	Not yet relocated		2.2		SP 0.87s. COR2	-32.069	117.717	
12Oct	2025	Not yet relocated		2.5			-32.101	117.733	
	* = depth constrained to this value								

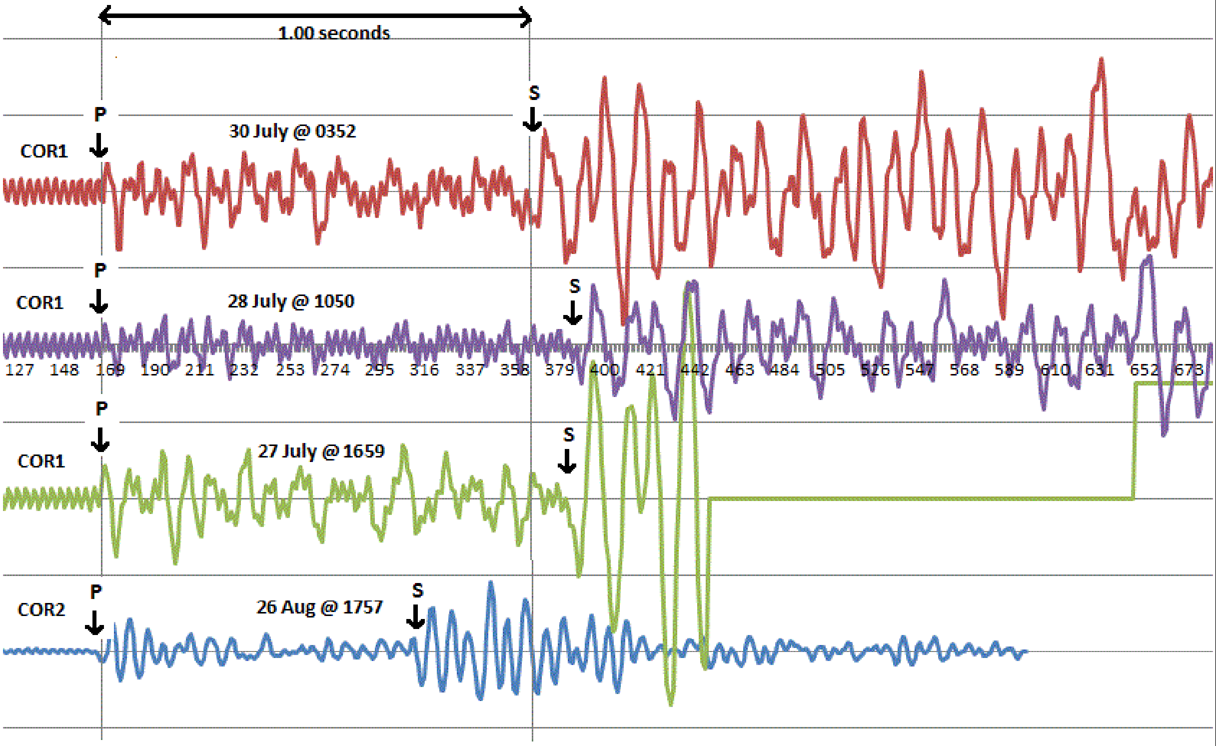
The earth model used in the relocations was WA2 (Dent 1989). This model was determined by inversion for velocity and location of phase data available in 1990, and indicated relatively high seismic velocities in the upper crust (P wave velocity ~ 6.1 km/sec). In the relocations of the 2017 events, it was usually necessary to constrain the focal depths at 2 km, as depths became negative in the inversion.

A trial relocation (Appendix 1A), for the small (ML 1.9) event of August 26th (with an arrival at COR2) was made using the DAL1A earth model, which was derived by McCue for the Dalton-Gunning region of NSW, using data published in Collins (1988) (McCue, Pers. Comm., 2017). The Dalton-Gunning region is granitic, with relatively high velocities, comparable to those of the Yilgarn craton of WA. However, the DAL1A model has a low velocity near-surface layer, approximating values predicted for the Yilgarn by Somerville & Ni (2010). An assumed S-P time of 1.0 secs for the COR1 station was also incorporated into the data. The new solution suggested a focal depth of 3.3 km, and brought the epicentral zone a little closer to the COR2 station. The uncertainties shown in the solution are unrealistically large because of the small amount of data used in the solution. A solution using the same data and the WA2 model gave a focal depth of minus 0.3 km (Appendix 1B). The more realistic depth from the DAL1A model suggests that further research is required to develop an earth model that suitably reflects the seismic velocities in the region.

6 Discussion

GA epicentres appear to define a NE trend over a region about 10 km long. However, this trend is probably introduced by poor azimuthal distribution of the GA seismographs around the events. The lack of a seismograph to the SE of the epicentral region means that epicentres are poorly constrained in that azimuth. The fact that many of the events plot close to, or under the Caporn's residence suggests a problem with the locations, as they would have been very noticeable. However, they barely noticed the events.

Figure 5 Waveforms of aftershocks recorded at field stations COR1 and COR2, showing the S-P intervals



The plot of historical activity suggests that the 2017 activity occurred at the same location as the 2000-2002 activity. The activity in 2017 contained more, and bigger events. The suggested common epicentre is 32.10°S, 117.82°E, estimated uncertainty +/- .02 degrees. The focal depths are shallow, estimated to be about 3 km, +/- 2 km. Going back further, the poorly located ML 3.5 event in 1988 may also have occurred at this location. This could suggest recurring activity on an approximate 15 year cycle, and the potential for larger events in this area is real.

The type and degree of activity described here might be considered "normal" for the SWA zone. It is similar in size and duration to clusters north of Quairading (January 1992), north of Woodanilling in 2013 (Dent 2014), and north of Koorda in 2011 (Dent 2012). None of the clusters in SWA so far studied have culminated in large magnitude events (ML ~5.0), although the farmer who house was seriously damaged by the ML 4.8 Broomehill earthquake of 2007 later reported that numerous small felt events had occurred in the weeks beforehand (Dent, 2008). Also, clusters of felt events had been reported in the Meckering area decades before the devastating 1968 event (Everingham, 1968, Dent, 2016).

This cluster's largest event was at the beginning of the sequence. In that respect, the sequence has main shock/aftershock nature. However, there were several events between Ml 2.8 and 2.9, i.e. less than half a magnitude unit below that of the main event (ML 3.3). In this respect, the activity could be described as being an "earthquake swarm" as it fits the criteria used by Love (2004), in an investigation of earthquake activity in the Eyre Peninsula of S.A. in 2003.

The uncertainty regarding the exact focal depths demonstrates the need for a deployment of at least 4-5 instruments around and over the next cluster in the SWA region. The relatively short duration of clusters such as this one demonstrates that rapid station deployment needs to be a priority.

An examination of data available from the Geol. Survey of WA (1:250,000 geology, and the magnetic anomaly map of the region) gives no indication of a causative fault or other feature which may be related to the seismicity. It is also remote from any features listed in GA's data base of neotectonic features.

Acknowledgements

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Appendix 1A

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Date            2017-08-26
Origin Time     1757 24.56   +-   8.76   solution using DAL1A model
Zone                    50
Easting             576.78   +-  84.72            Longitude     117.814
Northing           6447.90   +-  57.40            Latitude      -32.103
Depth                 3.31   +-  89.47

Arrival times    =  6          S.D. = 0.065        Seismographs =  5
Nearest recorder =    5.9 km    Gap  = 216.2 deg    Accuracy = C


   5 km  E (108 deg) of  COR2
WESTERN AUSTRALIA
 186 km  E ( 96 deg) of PERTH
  26 km  N (348 deg) of Corrigin

No magnitudes known                             Assign ML  1.9
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DATA USED

Code	Wave	AT	+-	WT	CT	DT	Dist	Azim	Ad	Ae
COR2	P	25.79	0.02	2.14	25.74	0.05	5.9	288	31.7	31.7
COR2	S	26.55	0.10	1.40	26.61	-0.06	5.9	288	31.7	31.7
COR1	S-P	1.00	2.00	0.84	1.08	-0.08	7.8	235	0.0	0.0
KLBR	P	34.34	0.10	1.32	34.39	-0.05	56.9	354	3.7	3.7
PING	P	39.99	0.05	1.46	39.94	0.05	89.3	239	-23.0	23.0
NWAO	P	42.57	0.10	1.25	42.65	-0.08	106.4	210	-23.0	23.0

6 times used, S = 0.065

Deferred Data

Code	Wave	AT	+-	WT	CT	DT	Dist	Azim	Ad	Ae
KLBR	S	40.78	0.50	0.86	41.58	-0.80	56.9	354	3.7	3.7
KULI	P	40.99	0.05	1.49	36.75	4.24	70.6	153	3.0	3.0
KULI	S	45.50	0.50	0.84	45.67	-0.17	70.6	153	3.0	3.0
PING	S	50.35	0.50	0.83	51.19	-0.84	89.3	239	-23.0	23.0
MUN	P	48.97	0.20	1.06	49.92	-0.95	152.2	274	-23.0	23.0
MUN	S	66.90	1.00	0.69	68.46	-1.56	152.2	274	-23.0	23.0
BLDU	P	54.77	0.10	1.19	56.17	-1.40	195.8	327	-37.9	37.9
BLDU	S	78.70	1.00	0.68	79.32	-0.62	195.8	327	-37.8	37.8

Appendix 1B

Date	2017-08-26		
Origin Time	1757 24.95 +- 44.89	**solution using WA2 model**	
Zone	50		
Easting	576.93 +- 252.54	Longitude	117.815
Northing	6449.45 +- 200.36	Latitude	-32.089
Depth	-0.30 +- 557.50		

Arrival times = 5	S.D. = 0.109	Seismographs = 4
Nearest recorder = 5.7 km	Gap = 288.2 deg	Accuracy = C
Effects Code =	Imax = 0	Fault =

5 km E (93 deg) of COR2
WESTERN AUSTRALIA
186 km E (95 deg) of PERTH
27 km N (349 deg) of Corrigin

No magnitudes known Assign ML 1.9

DATA USED

Code	Wave	AT	+-	WT	CT	DT	Dist	Azim	Ad	Ae
COR2	P	25.79	0.02	2.14	25.88	-0.09	5.7	273	-0.0	-0.0
COR2	S	26.55	0.10	1.40	26.53	0.02	5.7	273	-0.0	-0.0
COR1	S-P	1.00	2.00	0.83	1.00	-0.00	8.8	227	0.0	0.0
QUAI	P	31.74	0.10	1.36	31.57	0.17	40.6	282	0.0	0.0
NWAO	P	42.57	0.10	1.25	42.54	0.03	107.8	210	-0.0	-0.0

5 times used, S = 0.109

Deferred Data

Code	Wave	AT	+-	WT	CT	DT	Dist	Azim	Ad	Ae
QUAI	S	36.50	1.00	0.77	36.16	0.34	40.6	282	0.0	0.0
KLBR	P	34.34	0.10	1.32	33.99	0.35	55.4	354	0.0	0.0
KLBR	S	40.78	0.50	0.86	40.26	0.52	55.4	354	0.0	0.0
KULI	P	40.99	0.05	1.49	36.69	4.30	72.0	153	0.0	0.0
KULI	S	45.50	0.50	0.85	44.83	0.67	72.0	153	0.0	0.0
PING	P	39.99	0.05	1.46	39.67	0.32	90.2	238	-0.0	-0.0
PING	S	50.35	0.50	0.83	49.88	0.47	90.2	238	-0.0	-0.0
MUN	P	48.97	0.20	1.06	49.50	-0.52	152.2	274	-30.8	30.8
MUN	S	66.90	1.00	0.69	67.00	-0.10	152.2	274	-0.0	-0.0
BLDU	P	54.77	0.10	1.19	55.18	-0.42	194.6	327	-42.2	42.2
BLDU	S	78.70	1.00	0.67	77.71	0.99	194.6	327	-40.3	40.3