THE 2001/02 BURAKIN AND 1968 MECKERING WA EARTHQUAKES

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Abstract

Waveforms recorded during a sequence of earthquakes near Burakin WA in 2001/02 are used in a Green's Function simulation of the 1968 Meckering earthquake and the results discussed to add to our knowledge base of WA's third largest earthquake in modern times.

The accelerograms of the 23rd of March 2002 event of the ML4.6 foreshock recorded by the stations at a close distance was used to simulate a moderate size earthquake. The synthetics produced by the summation method were compared with the actual records of the Burakin ML5.2 earthquake on 30th of March 2002. Then, the waveforms from the Burakin 2002 earthquake magnitude ML5.2 recorded at the station 120km away, located on the Darling Fault scarp, were used as sub-events in a combined Green's Function simulation.

These synthetics could be applicable to Perth, if in the modelling the earthquake origin is centred on Meckering. Besides matching the epicentral distance and the frequency characteristics, the simulated data representing the Perth basin should be corrected for local geology to account for the sedimentary basin and regolith underneath the city area. Thus, these Green's Function simulation results can be selectively used in dynamic testing of structural behaviour during typical earthquakes originating in the South-West Seismic Zone (SWSZ).

Keywords: seismicity, earthquake records, simulation

1. INTRODUCTION

Records of smaller earthquakes can be used to simulate strong ground motion from larger events where insufficient data exist. In intraplate Australia, there is a lack of close range records from the largest earthquakes due to its sparse seismic networks and relatively short period of instrumentation. In designing the Building Codes, scientists and engineers frequently use macroseismics from the historical events and comparable records from other parts in the world (for example, Sinadinovski and McCue, 2003).

Here, we analysed selected instrumental records of the Burakin 2001/02 seismic swarm for their frequency and amplitude characteristics, in order to study the regional attenuation characteristics. Those records were compared with the macroseismic maps of intensity and utilised for simulation of a magnitude Ms6.8 earthquake centred on Meckering, to relate to the 1968 scenario. The simulated accelerograms are viewed with the previously published synthetics by the same research group (Sinadinovski et al., 2005a, Liang et al., 2006).

The strong motion synthetics of the earthquakes in the South West Seismic Zone of WA can be used for dynamic analyses of buildings in the city of Perth and its suburbs. The results of these tests are very valuable across a range of disciplines involving multiple engineering aspects and improving the seismic risk assessment (Sinadinovski et al., 2005b).

2. MACROSEISMIC DATA

The 14th October 1968 Meckering earthquake was one of the largest recorded in Australia and the first known to cause surface faulting. The earthquake was felt throughout the southern half of Western Australia and resulted in considerable damage documented in numerous reports (Everingham and Gregson, 1970; Gordon and Lewis, 1980). The magnitude Ms6.8 earthquake was located in a zone of seismic activity which is about 150km east of Perth, in the Archean Yilgarn Block. That is seismically the most active region of Australia, known as the South-West Seismic Zone (SWSZ) (Sinadinovski et al., 2005b).

Figure 1 shows the macroseismic map for the Meckering 1968 earthquake, that was felt over an area 700km in radius. The maximum intensity in the epicentre was MM-IX and the significant damage was confined to the area within the MM-VI isoseismal. In Perth the intensity was commonly MM-V, though MM-VI occurred in a few places due to local soil conditions. The shape of the isolines showed that the shaking was propagated more to the east, which could be correlated with the geological structure of the Yilgarn craton, that consists of the granite plutons remnants of older gneiss and younger dolerite dykes.

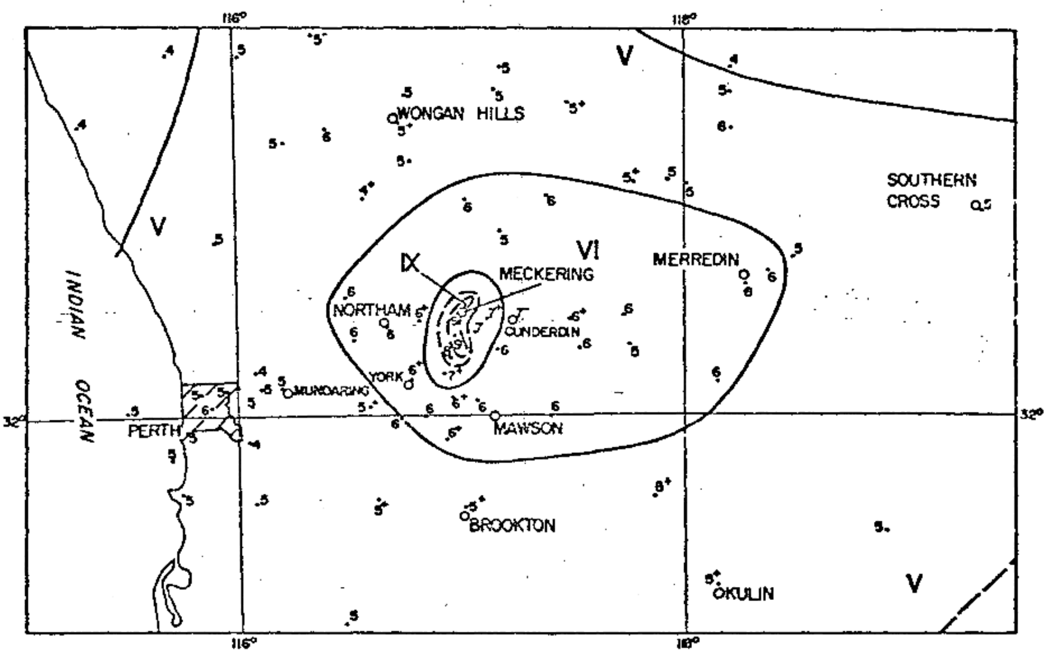

Figure 1: Isoseismal map of the Meckering 1968 earthquake magnitude Ms6.8

The Burakin sequence of 2001/02 presented a unique opportunity to study small-to moderate magnitude earthquakes recorded at very close distances, as well as over a range of up to 190km. The earthquake swarm started back in 2000 near the town of Burakin, with a ML5.1 event on 28th September 2001, followed by more than 16,000 aftershocks, culminating on 30th March 2002 with a magnitude ML5.2 event (Leonard, 2003).

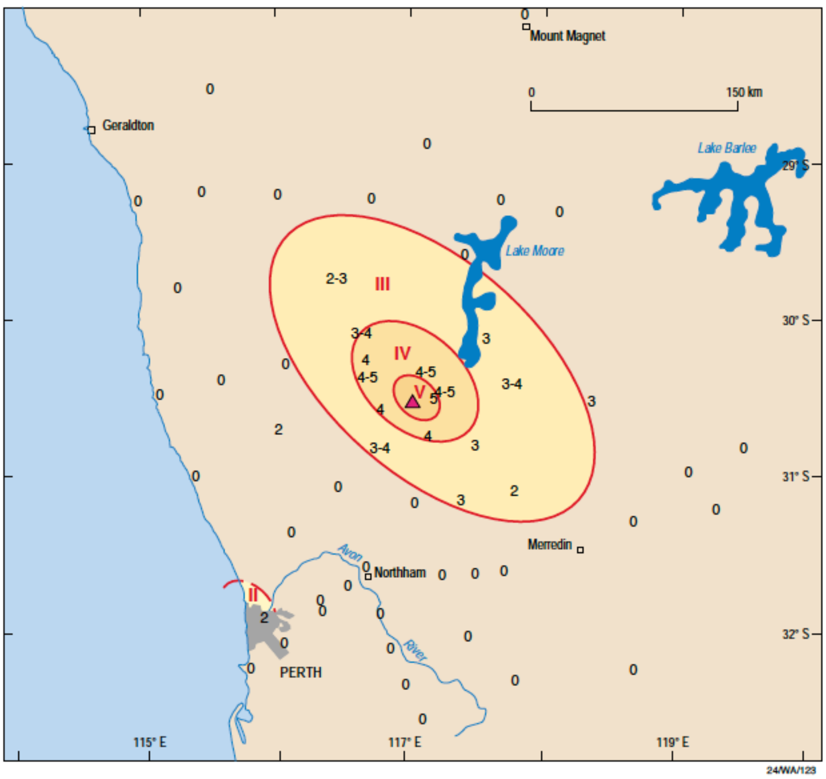

Figure 2: Isoseismal map of the Burakin 2001 earthquake magnitude ML5.1

Besides the isoseismal maps, other data comprised subsets of Geoscience Australia's Earthquake list for Australia, geological maps for the region around Perth, the fault plane solutions for the larger events and the fault scarps database. Figure 3 shows the geology of the area with the main features.

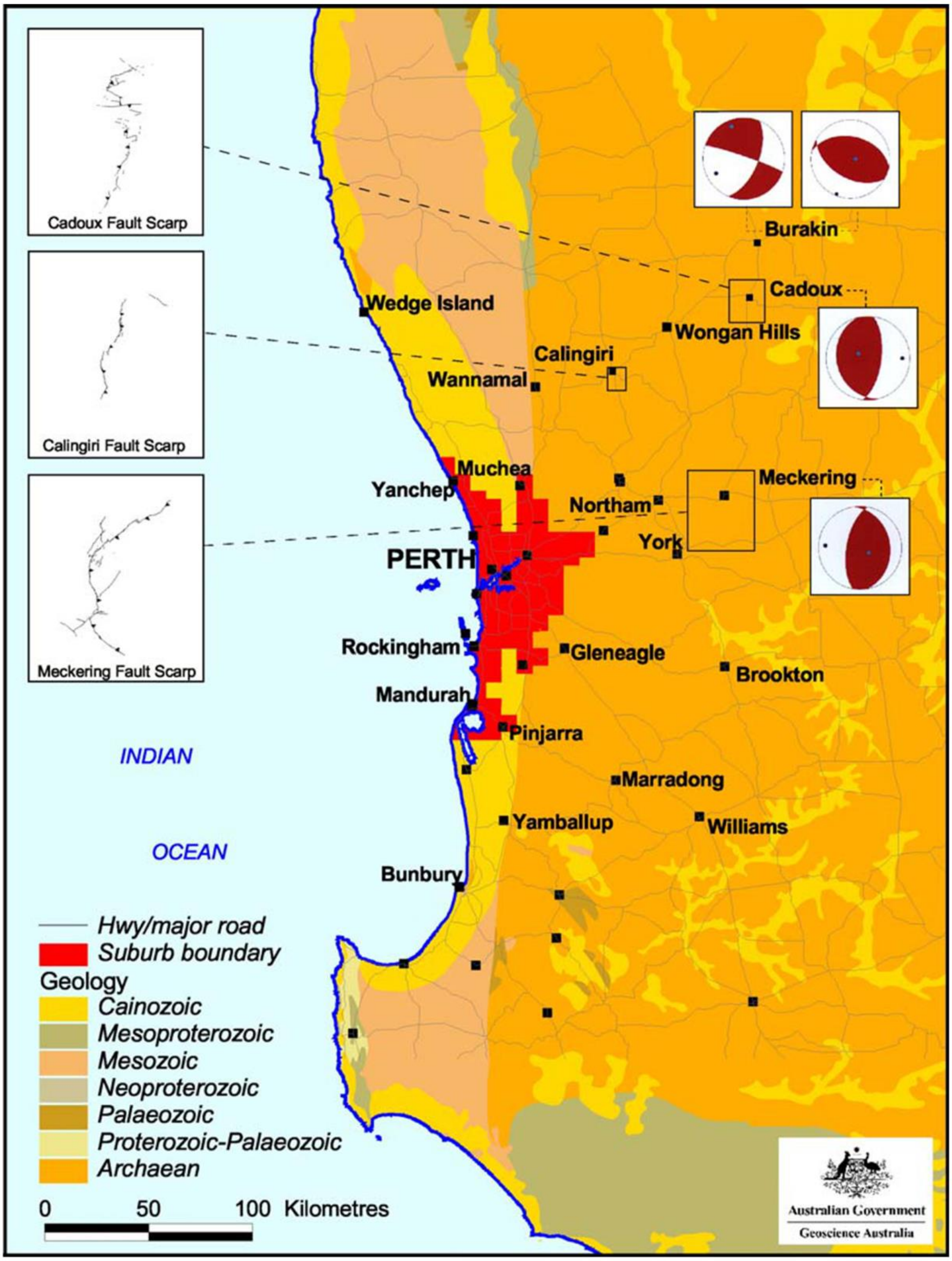

Figure 3: Geology of the region showing fault scarps for the three largest earthquakes, Meckering, Cadoux and Calingiri. Fault plane solutions are shown for Meckering, Cadoux and the two Burakin 2001/02 earthquakes (after Sinadinovski et al., 2005b).

The block associated with the Meckering fault was a 37 km segment of a saucer shaped body. Fault movement appeared to be a dextral strike-slip of 0.5 m, combined with a thrust movement varying from zero at the end of the fault to a maximum of about 2 m at the centre. The model proposed to explain such features involved the straining of a superficial circular cap of rock by sinistral movement on an underlying shear zone (Gordon and Lewis, 1980). The essential points of that model had been confirmed by field studies of the uplifted parts and were transferred into the simulation process.

3. INSTRUMENTAL RECORDS

Following the first magnitude 5.1 earthquake in September 2001, Geoscience Australia deployed a number of seismographs/accelerographs in the area in addition to the existing ones from the National Network and the Joint Urban Monitoring Program (Sinadinovski et al., 2005b).

The horizontal components of the 30th of March 2002 magnitude ML5.2 earthquake recorded on ten stations are displayed on Figure 4. The reduced travel time of (t-Δ/8) was used to plot the ordinate. The earthquake epicentre was located, using the network of permanent and temporary stations (inset), at longitude 117.049^{o}E and latitude 30.524^{o}S, with a shallow depth of 5km.

Plotting of the waveforms and conversion was done using a freeware package called *Waves* courtesy of the Seismology Research Centre (SRC) in Melbourne. The units on the *y*-axis are displayed as counts and later converted into acceleration (*g*) based on the settings of each of the instruments.

After reviewing the seismograms, two sets of records were selected for earthquakes between magnitude ranges ML4.6-ML5.2 and epicentral distance from 10km to 190km. The three component accelerogram recorded by the station BK1 of the magnitude ML5.2 Burakin earthquake is displayed on Figure 5, and of the magnitude ML4.6 Burakin foreshock that happened a week earlier is shown on Figure 6.

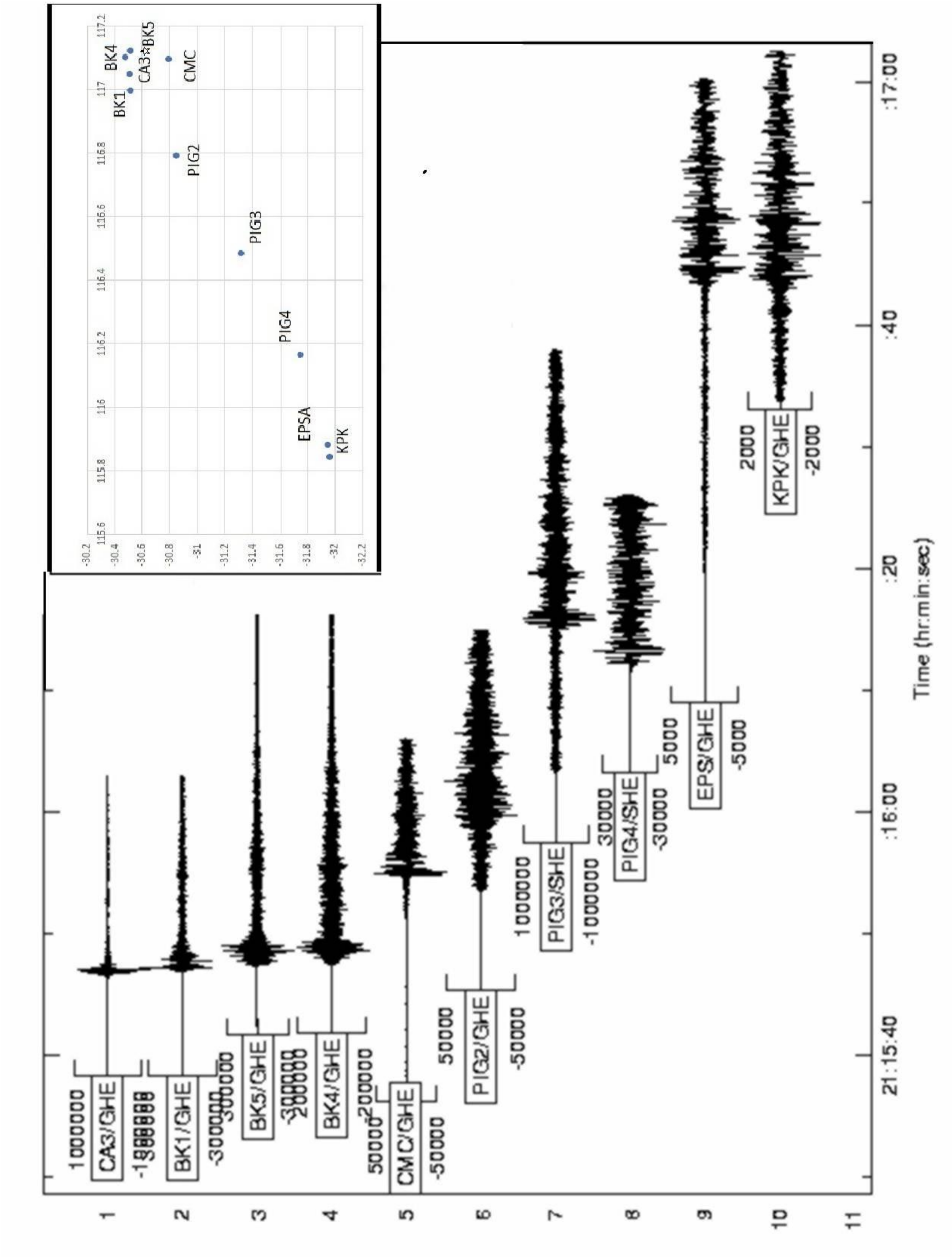

Figure 4: Seismic records (horizontal component) of the magnitude ML5.2 Burakin earthquake on 30th March 2002 (21:15 UTC). Inset: spatial station distribution.

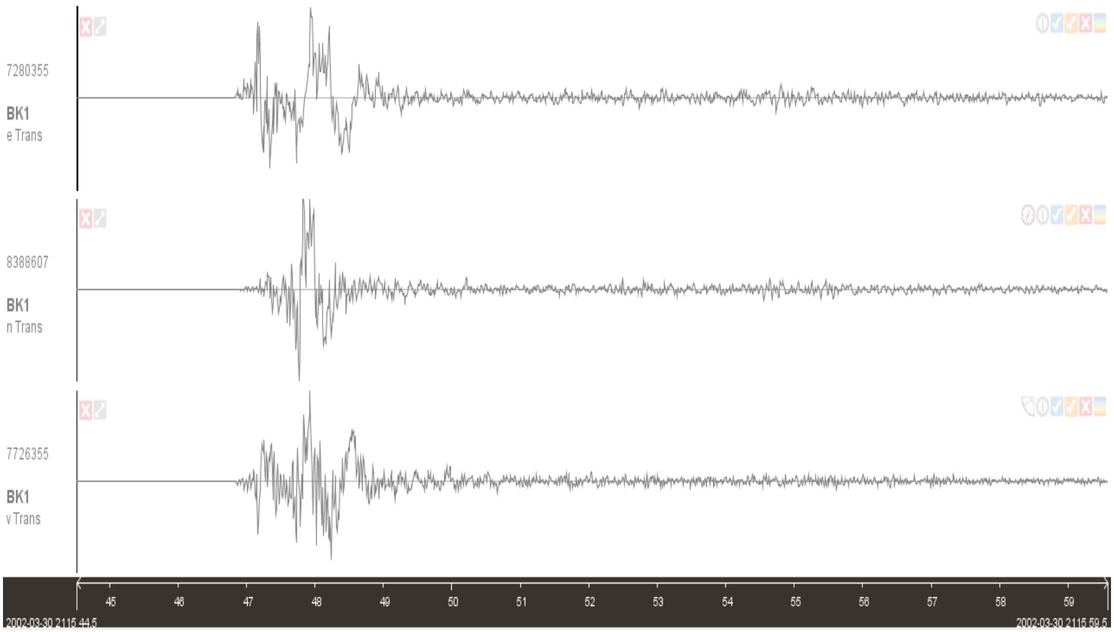

Figure 5: The three component accelerogram of the magnitude ML5.2 Burakin earthquake on 30th March 2002 (21:15 UTC). recorded by station BK1. (N, E, Up)

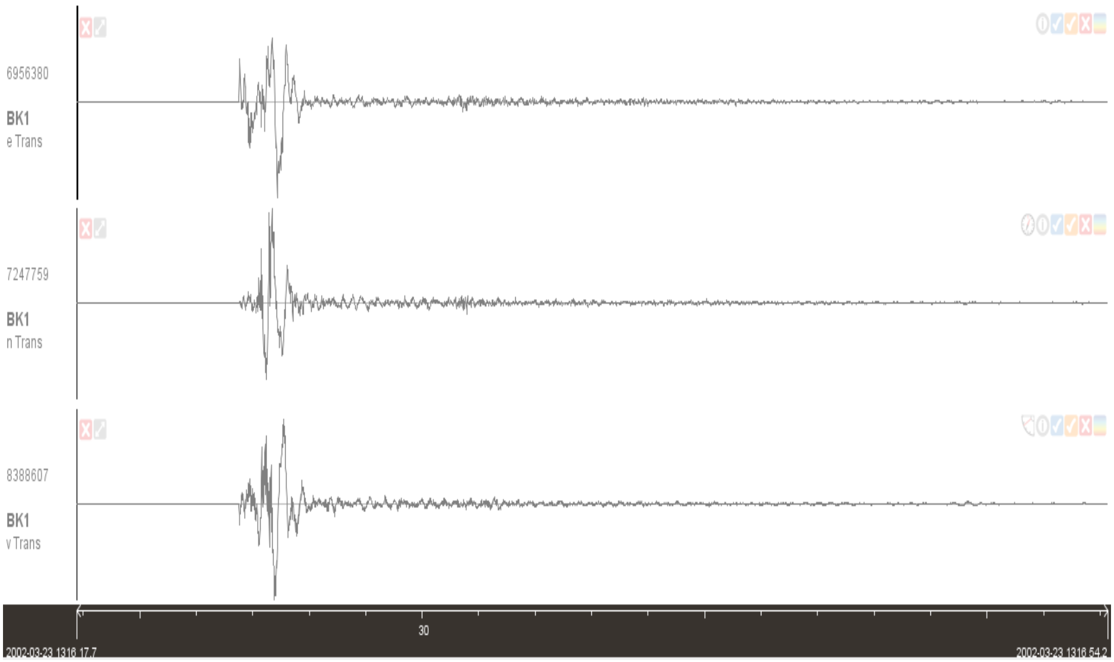

Figure 6: The three component accelerogram of the magnitude ML4.6 Burakin foreshock on 23rd March 2002 (13:16 UTC). recorded by station BK1. (N, E, Up)

4. MODELLING

The accelerogram of the 23rd of March 2002 event of the ML4.6 foreshock recorded by station BK1 at a distance of 10km was used in the first simulation. The empirical Green's Function method of superposition assumes that the source parameters, path and site effects for the main event and its foreshocks/aftershocks are equivalent.

It should be noted that simply summing small events, as the original Green's Function method proposed, with delayed time, could underestimate the low-frequency signal (Liang et al., 2006). The modified method used here can overcome that situation. In our approach, the waveforms of the smaller magnitude events recorded at different distances are convolved in the time domain. Then, their Fourier transforms are pointwise multiplied and later the inverse Fourier transform taken to de-convolve the combined waveform. We searched many cases and eliminated ones that gave unrealistic ground motions.

In extrapolating from earthquake magnitude ML4.6 to the stronger earthquake magnitude ML5.2, the source parameters were set to a rupture length of 2km, keeping the terms in the spectral formula. In this production of the synthetics (Fig. 7) a rupture velocity of 2.25km/s was used and a surface fault was oriented perpendicular to the source-receiver line. The procedure was applied using Allen et al., 2006 calculations, in one step summing over an area for 5 sub-events which progressively brought the magnitude to around 5.2. During the stochastic simulation, the values were kept in counts and later converted into *g* based on the instrument calibration information.

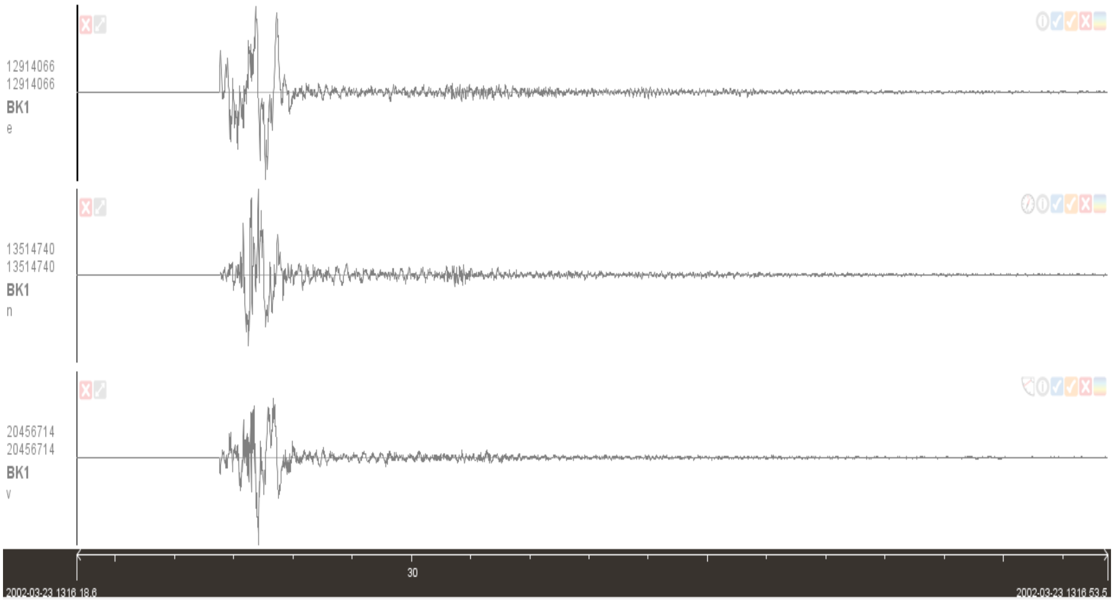

Figure 7: The three component synthetic accelerogram of the magnitude ML5.2 event.

The maximum values for the recorded ML4.6 earthquake at station BK1 were 0.085g on the horizontals and 0.1g on the vertical component. The maximum values for the recorded ML5.2 earthquake at station BK1 were 0.2g on the horizontals and 0.19g on the vertical component. The maximum values for the synthetic ML5.2 earthquake at a hypocentral distance of 10km were 0.14g on the horizontal and 0.2g on the vertical component, which closely matched the observed values.

The simulated motions agree well with the recorded ground motions in a wide frequency band too. The Fourier Amplitude Acceleration spectra of both recorded ML4.6 and ML5.2 earthquakes at station BK1 and of the synthetic at hypocentral distance of 10km are displayed versus frequency on the following Figure 8.

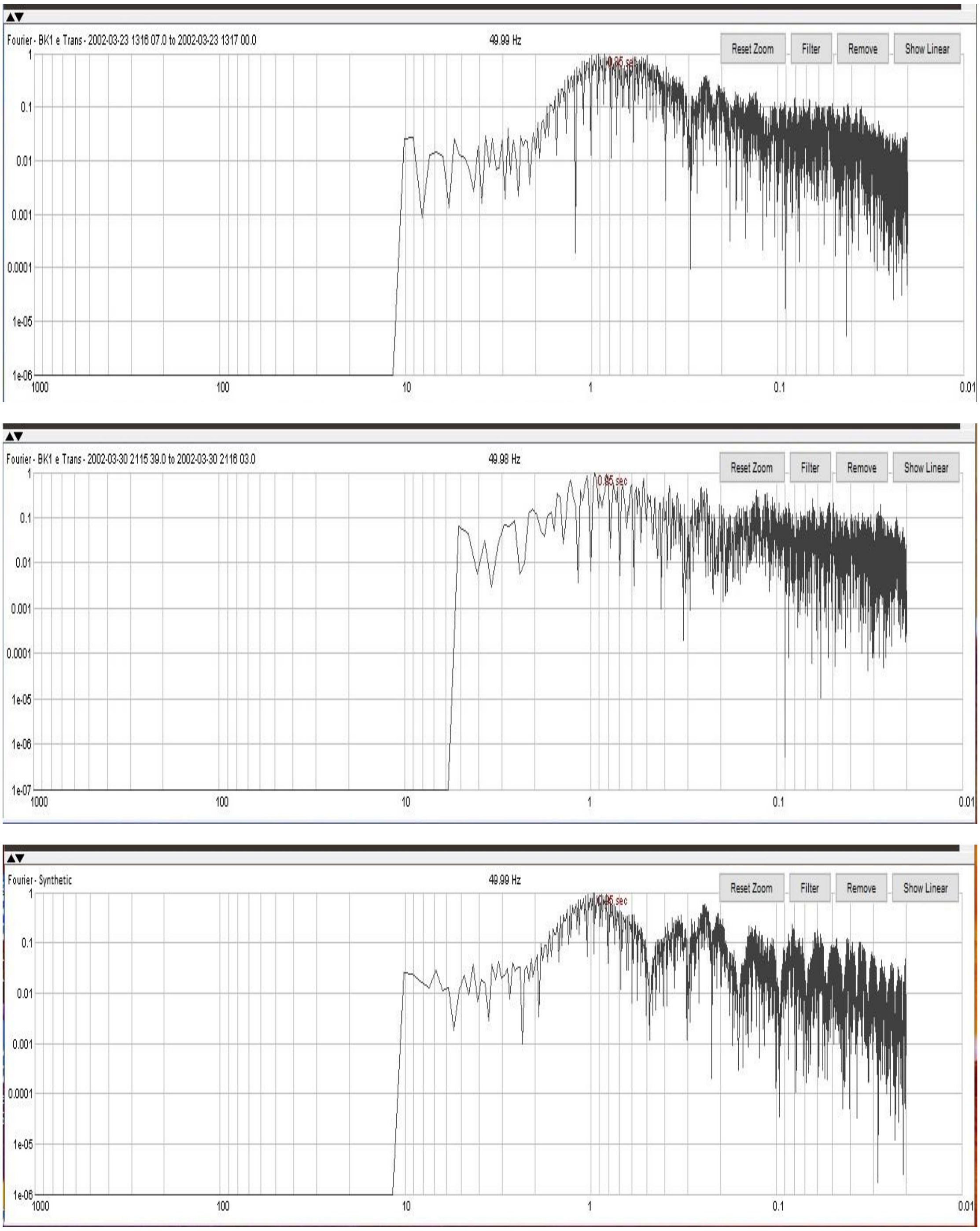

Figure 8: The Fourier Amplitude spectrum of the seismograms in log-log scale: Top-recorded magnitude M4.6 Burakin earthquake at station BK1; Middle-recorded ML5.2 Burakin earthquake at station BK1; Bottom-the synthetic record produced for the ML5.2 event at a distance of 10km.

In the earlier work by Sinadinovski et al., (2005a), the empirical Green's Function method was applied to produce a moderate to large magnitude earthquake ML~6, from a magnitude ML5.2 sub-event recorded at station BK5, at a similar epicentral distance of 10km. The acceleration response spectra of the simulated BK5 record with 5% damping was compared with the Australian Loading Code (Standards Australia, 1993) for rock site (Figure 9). The simulated waveforms were normalised in order to give an indication of its suitability in terms of the shape and the frequency content. It was found that the code spectra in general overestimates the spectral acceleration of the synthetics, especially the period range of 0.3 to 3 sec which covers the fundamental natural periods of most common structures.

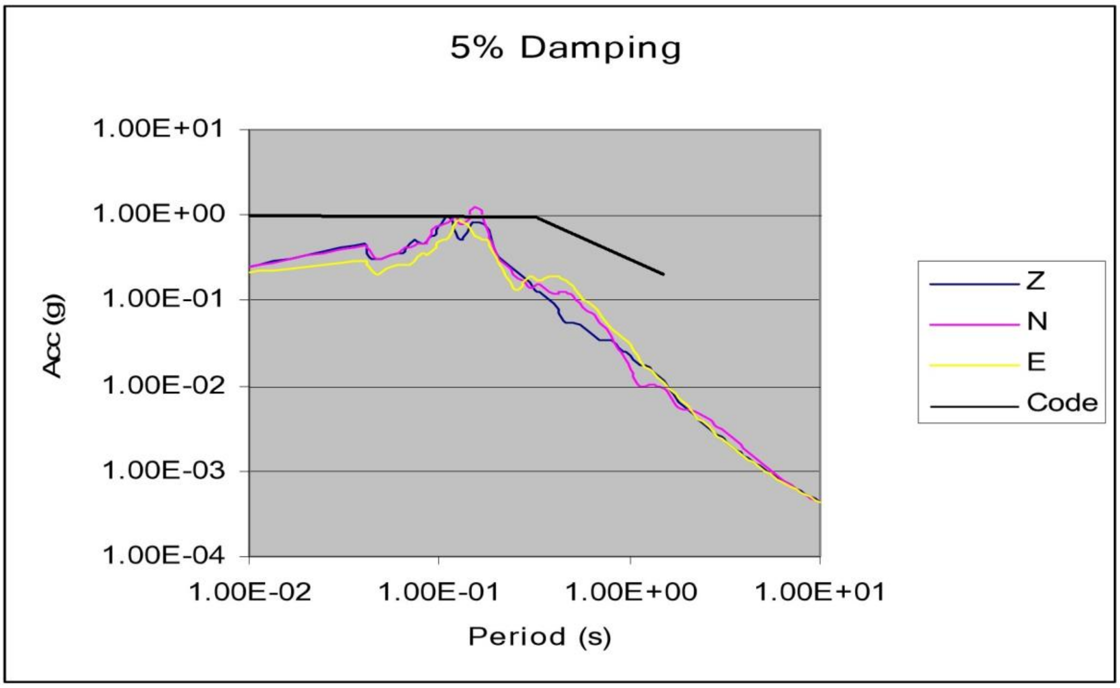

Figure 9: Combined acceleration spectra for the Burakin synthetics with 5% damping

Fourier Amplitude spectra for the records were divided into three ranges according to the epicentral distance: close range up to 25 km, middle range 26 to 90km, and longer range greater than 90km. A typical shift from 30-50 Hz in the close stations towards lower frequency (5-8 Hz) for the more distant stations was noticed on the graphs.

For the simulation of the Meckering 1968 earthquake scenario, the waveforms from the Burakin 2002 earthquake magnitude ML5.2 recorded on the station at a far distance were used as sub-events. The records from the station named PIG4, located on the Darling Fault scarp at epicentral distance of 120km were selected. The recording was triggered by the arrival of the S-waves, but not triggered by the P waves. and due to the pre-set length of the window at 7 seconds, the first arrival was not saved to memory. Figure 10 shows the actual accelerogram recorded on station PIG4 and its corresponding Fourier Amplitude spectrum.

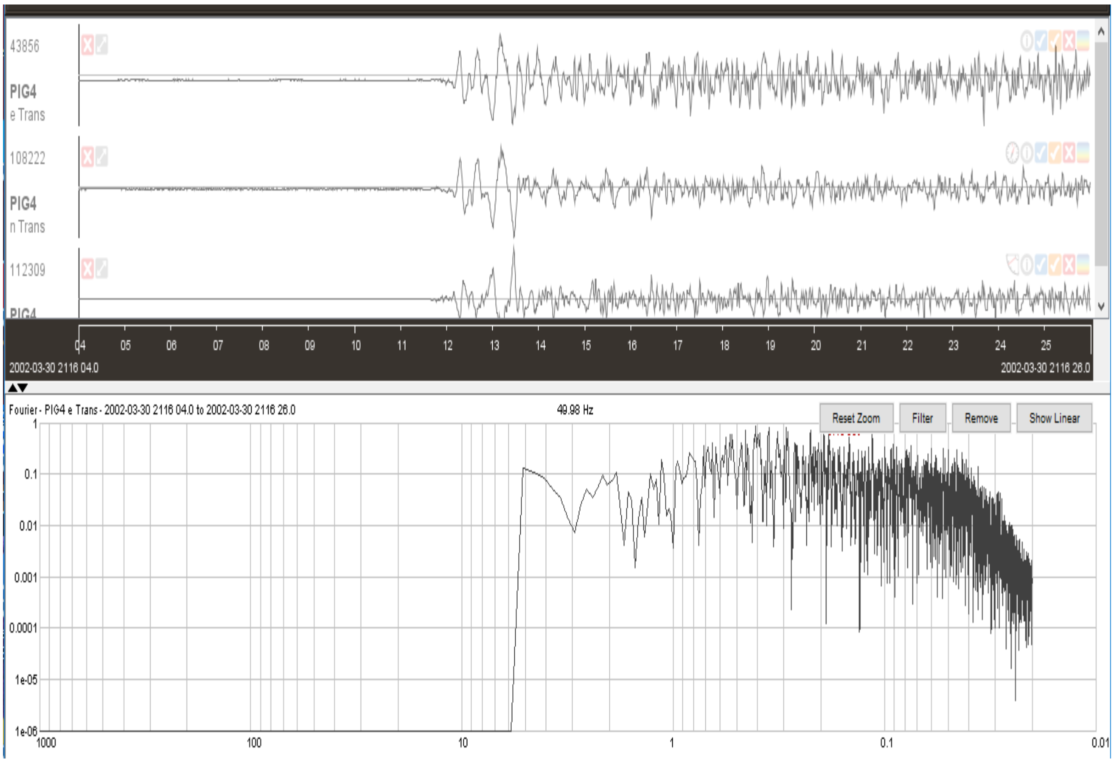

Figure 10: The three component accelerogram of the magnitude ML5.2 Burakin earthquake on 30th March 2002 (21:15 UTC), recorded at station PIG4 and its corresponding Fourier Amplitude spectrum.

The simulation was done in two stages: first, the sub-events were distributed onto a semi-circular fault of length 37km, with a rupture velocity of 2.25 km/s. Based on the relative seismic moment calculation, the procedure was applied in one summation over the area for 15 sub-events which would bring the event magnitude ML to the high 6's. Then their Fourier transforms were convolved and finally, the inverse Fourier transform taken from the combined waveform to compensate for the distance factor. Again, we searched multiple cases and selected the ones that gave the most realistic ground motions in shape and size.

During the simulation the values were kept in counts and later converted into *g* based on the instrument calibration information. The maximum values for the recorded ML5.2 earthquake at station PIG4 was measured to 0.054g on the horizontals and 0.056g on the vertical component. The maximum values for the synthetic Ms6.8 earthquake at distance of 120km were 0.1g on both the horizontal and on the vertical component, which is within the range reported in the literature (for example, Atkinson and Boore, 1997).

These synthetics are applicable to Perth, when the model is oriented in a way that the earthquake origin is centred on Meckering instead of Burakin. However, this applies within the Yilgarn craton, simulated data representing the Perth basin must be corrected for local geology that accounts for the crust and regolith underneath the city area (Sinadinovski et al., 2005b). Comparative analysis of the synthetics with the available records from the stations EPS and KPK in the Perth basin could be used to model this scenario.

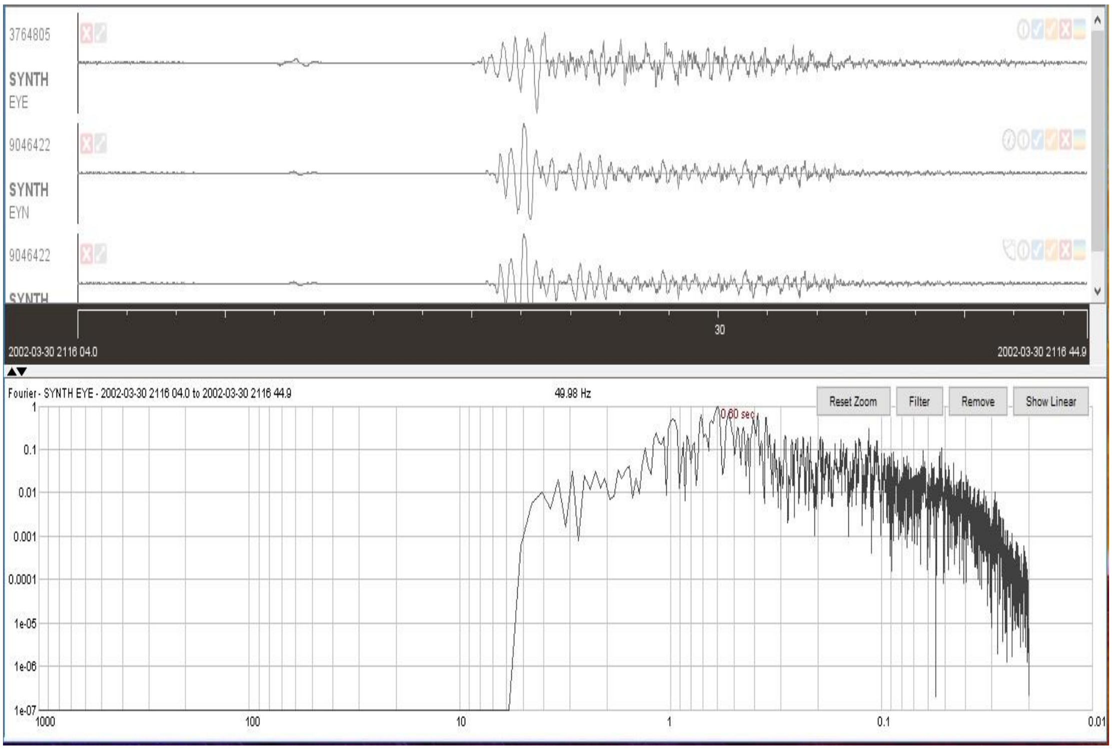

Figure 11: The three component the synthetic record produced for Ms6.8 event at a distance of 120km and its corresponding Fourier Amplitude spectrum.

5. SUMMARY

A prime interest in seismic risk assessment is the nature, period, duration and amplitude of the ground motion during major earthquakes. In the absence of close seismograph records of the shaking from the Meckering 1968 earthquake magnitude Ms6.8, rough estimates of maximum vibration were made based on intensity reports.

In this study a large magnitude earthquake was simulated for the Meckering 1968 scenario, from instrumental data acquired during the 2001/02 seismic swarm in Burakin, WA. Smaller magnitude sub-events recorded at various distances were used in a combined Green's Function method. This method of summation assumes that the source parameters, path and site effects for the main event and its foreshocks/aftershocks are equivalent. In our approach, the waveforms recorded at different distances are convolved in the time domain. Then, their Fourier transforms are pointwise multiplied and at the end, the inverse Fourier transform taken to de-convolve the combined waveform. By changing the input parameters, we searched combinations that gave more realistic ground motions.

The accelerogram of the 23rd of March 2002 event of the ML4.6 foreshock recorded by the station BK1 at a close distance of 10km was used in the first simulation for moderate size earthquakes. The synthetic produced by the summation was compared with the actual record of the Burakin ML5.2 earthquake on 30th of March 2002. The results are in agreement with the station measurements and consistent with the earlier work reported by these authors.

In the second part, the waveforms from the Burakin 2002 earthquake magnitude ML5.2 recorded on the station at 120km distance were used as sub-events. Records from the station located on the Darling Fault scarp were selected in the combined Green's Function simulation. These synthetics are applicable to Perth, if in the modelling the earthquake origin is centred on Meckering.

Besides matching the epicentral distance and the frequency characteristics, the simulated data representing the Perth basin need to be corrected for local geology to account for the sedimentary basin and regolith underneath the city area. Comparative analysis of the synthetics with the available records from the stations in the Perth area could further substantiate these results.

Previous validation studies for similar events in Australia have shown that synthetics produced by this method are comparable with the Loading Code AS 1170.4, and can realistically represent ground motion during intra-plate earthquakes (Sinadinovski et al., 2005a). Therefore, these Green's Function simulation results can be selectively used in dynamic testing of structural behaviour during typical earthquakes.

6. ACKNOWLEDGEMENT

We acknowledge Geoscience Australia for supplying the selection of their instrumental records from the WA stations deployed to monitor the Burakin 2001/02 swarm of earthquakes. We thank SRC in Melbourne for allowing us to use the latest version of the *Waves* software.

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