Developing a seismotectonic model using neotectonic setting and historical seismicity

Application to central New South Wales

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Abstract

We present the methodology behind the development of a seismotectonic model that attempts to bridge the gap between models derived either from the (limited) historic record of seismicity, or high-resolution neotectonic models that consider only faults that are known to be active.

Detailed information regarding local geology, in particular relating to late Tertiary and Quaternary deformation, in combination with an updated catalogue of historical seismicity, were used to refine the AUS5 seismotectonic model for the central New South Wales region. Nearby major geological faults have been investigated in order to determine whether neotectonic activity is evident. Faults believed to have been active in recent geological time and that are consistent with the current stress regime have been assigned an estimated slip rate. A number of active faults have now been included in the model and several new zones have been introduced.

In comparison with the previous AUS5 model for the central New South Wales region, the resulting earthquake hazard estimates have decreased for sites furthest from faults. For sites close to faults identified as active, earthquake hazard estimates have increased, particularly for faults assigned a significant slip rate.

Introduction

Seismotectonic models are typically used for earthquake hazard assessments, by separating a region into sources of seismicity, commonly areas. These differ in characteristics such as earthquake recurrence rate, the relative number of small to large events, and the maximum credible magnitude earthquake - values based on data from catalogues of historical seismicity (Gutenberg & Richter, 1964; Cornell, 1968). Other models may consider only faults which are known to have been active in recent geological time. Both approaches, when considered independently, have limitations in their application.

As in any region, earthquake catalogues available for southeastern Australia are temporally and spatially limited. Prior to sensitive seismograph networks, earthquake locations were derived from felt reports. Thus, reported events were biased towards large earthquakes or those felt within populated areas. Seismograph networks in Australia now allow for some smaller and more remote earthquakes to be located. However, much of Australia remains poorly covered and network coverage varies with time and locality. Another concern is the period captured by current historic records, which is much shorter than the return period of moderate and large earthquakes in Australia, while emphasising the (misleading) effects of earthquake clustering. Consequently, historical earthquake seismicity is not necessarily a good indicator of earthquake hazard.

Neotectonic models consider those faults that are known to have been active in recent geological time, in particular the late Tertiary and Quaternary. These models aim to consider fault activity over the period of the present tectonic stress field, usually the last few million years, giving a more realistic indication of long-term seismicity, especially in regions of low seismicity such as Australia. Faults are normally deemed active if they exhibit a geomorphic expression, such as a scarp. However, modification of surface expressions over time, through ongoing geological processes such as erosion, may conceal a surface rupture or yield a scarp of non-tectonic origin. Also, many active faults can be blind faults that do not rupture the surface.

Figure 1: Area of interest

The AUS5 seismotectonic model defined by Brown and Gibson (2000, 2004) provided a national model over those models previously developed for Australia, particularly in southeastern Australia. The AUS5 model divides Australia into zones based on seismic activity and major geological boundaries, however the model for central New South Wales was based almost entirely on historical seismicity and included no active faults.

This paper outlines the process leading to the modifications to the AUS5 model for the central New South Wales region (Figure 1), using geological data and historical earthquake records in order to identify active faults as earthquake sources, and to improve the surrounding area sources accordingly.

Geological and seismic evidence of neotectonic activity

Initial investigations of neotectonic activity were based on previous geological and geophysical studies of the central New South Wales region. Published geological maps (eg. Raymond & Pogson, 1998; Morgan et al., 1999) indicate that a number of faults cross the central New South Wales region, many of which developed during deformation events of the Palaeozoic and Mesozoic (Scheibner & Basden, 1996). Of particular interest to this investigation were those major faults which align approximately north-south, consistent with the current east-west compressional stress experienced by central New South Wales (Hillis et al 1999; Clark & Leonard, 2002; Reynolds et al., 2002). Gravity and aeromagnetic geophysical data were also examined to identify any similarly oriented lineaments which may not be obvious in the outcrop geology.

The historic record of seismicity for the region was compared with the information obtained from published geological and geophysical investigations. Of relevance were zones of seismicity aligned approximately north-south, consistent with the current stress regime of central New South Wales. It was observed that a number of faults identified in the structural geology were, perhaps not surprisingly, associated with areas of high seismicity (relative to surrounding areas) with activity occurring under the up-thrown block of the fault, as expected with reverse faulting.

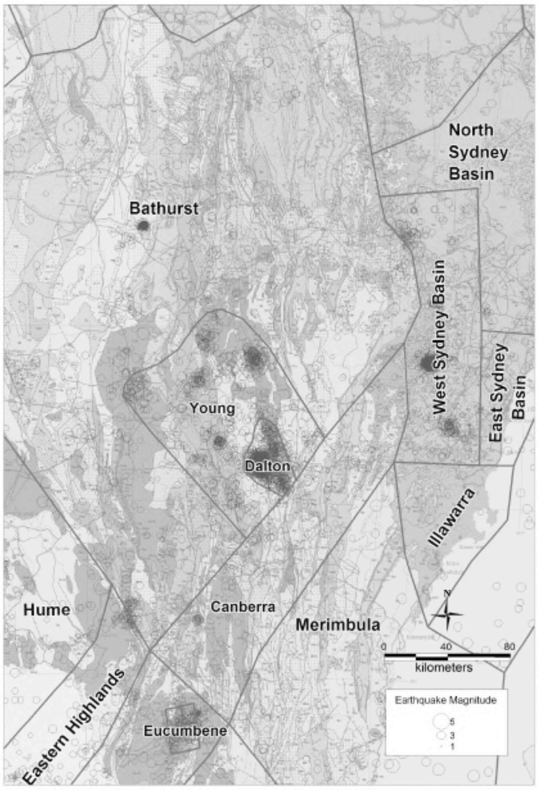

Figure 2: AUS5 model for central New South Wales – original.

A field investigation was conducted at a number of geological and geophysical lineaments in search of geomorphic features which may provide evidence of neotectonic activity. The ages of displaced geological units were used to interpret when these structures may have most recently been active. Given that the current stress field is assumed to have developed from about the late-Miocene (Sandiford et. al., 2004) any activity over the past 15 million years is significant.

It has been assumed that the current long-term rate of activity is best represented by deformation in the past one million years, during the Quaternary. Faults exhibiting evidence of neotectonic movement were assigned an average rate of slip (in metres per million years) based on vertical displacement estimated to have occurred during this time.

Faults that exhibited geomorphic evidence of seismic activity, such as vertical displacement visible as a scarp, were assigned a higher slip rate. Faults whose neotectonic activity could not be supported by geomorphic markers but which still aligned with higher levels of seismicity were assigned a lower slip rate.

Results, discussion & future work

As a result of this study, a percentage of seismicity previously assigned across the whole seismotectonic zone (Figure 2) has now been assigned to a number of faults within the zone (Figure 3).

The active faults are defined as three-dimensional sources – earthquakes of all magnitudes up to a maximum of M 7.5 can occur anywhere along the fault and to a depth of approximately 20 kilometres. The background seismicity has been reduced, but still incorporates seismic activity not associated with known faults.

Overall, earthquake hazard estimates for a site situated close to an active fault compute a higher hazard than a site far from an active fault.

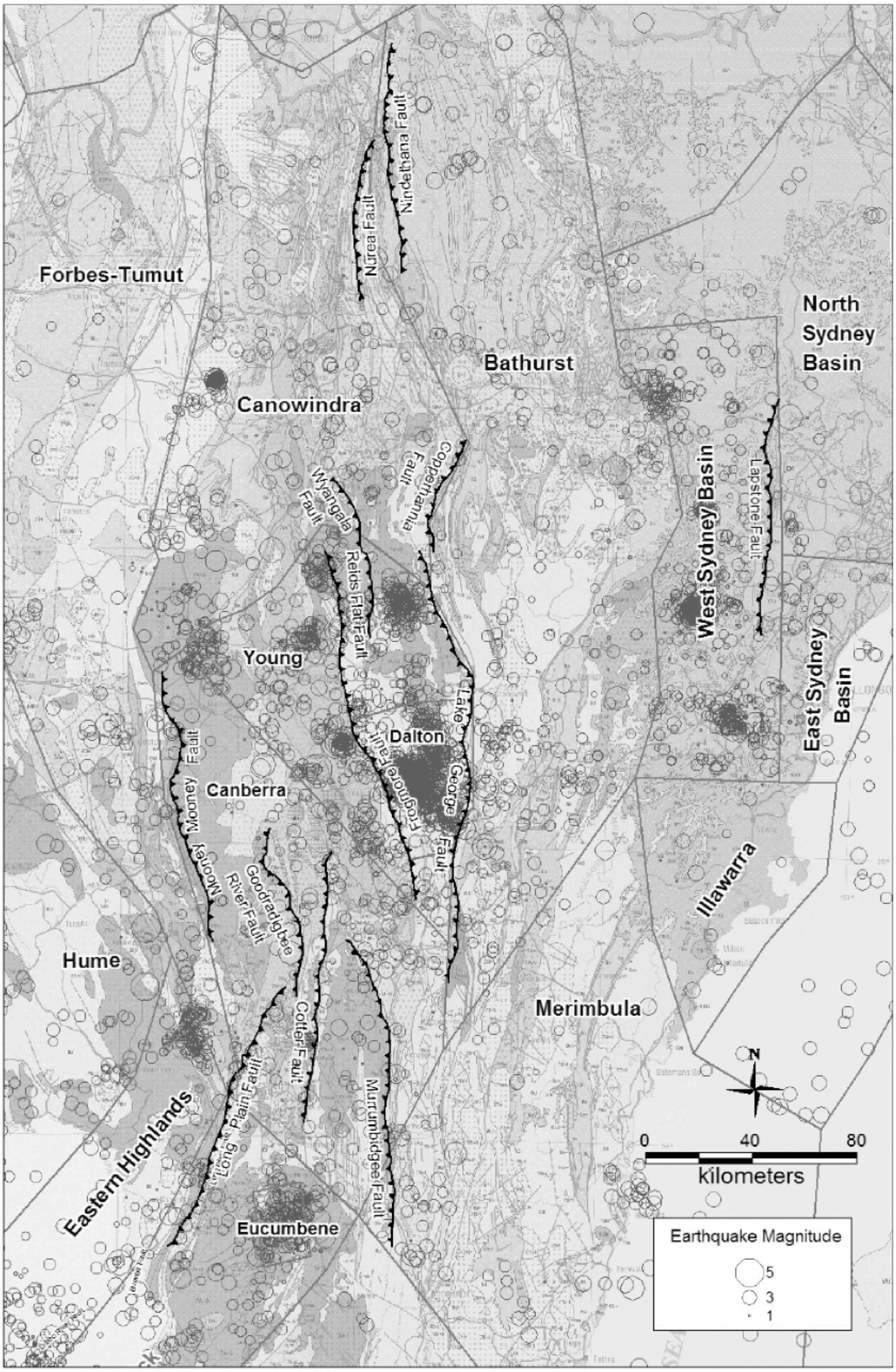

Figure 3: AUS5 model for central New South Wales – refined, showing faults now considered in seismotectonic model. Geology by Scheibner (1997).

Table 1: Faults included in the refined AUS5 seismotectonic model for central New South Wales, showing estimated slip rates.

FAULT	MECHANISM	LENGTH (km)	SLIP RATE (m/million yrs)
Long Plain	West dipping reverse	110	5
Mooney Mooney	East dipping reverse	110	5
Goodradigbee	West dipping reverse	70	5
Cotter	West dipping reverse	105	5
Murrumbidgee	West dipping reverse	122	5
Frogmore North Middle South	East dipping reverse	67 58 15	5 10 5
Wyangala	West dipping reverse	31	5
Reids Flat Thrust	West dipping reverse	35	5
Lake George North Middle South	West dipping reverse	61 59 51	10 15 5
Copperhannia	West dipping reverse	48	5
Nurea	East dipping reverse	63	5
Nindethana	East dipping reverse	90	5
Lapstone	West dipping reverse	92	30

At this stage fault slip rate values presented here (Table 1) are preliminary, influenced by available geological evidence and comparisons with other faults within the region that have better defined slip rates. The further quantification of activity along individual faults requires additional seismic and geological information. Accurately located earthquake hypocentres could be assigned to activity along a specific fault, allowing for magnitude recurrence estimates. Palaeoseismological studies could contribute information such as characteristic earthquake magnitude, frequency of occurrence, and displacement estimates likely to be produced along each fault.

Conclusion

Evidence of neotectonic activity gleaned from geological data has been compared with historical seismicity in order to locate active fault sources and to refine the area sources of the AUS5 model for central New South Wales. The original AUS5 seismotectonic model for this region was based almost entirely on historical seismicity and displayed limited correlation with the local geology.

A number of faults in the region have been assigned an estimated slip rate based on geomorphic evidence. As a percentage of earthquake activity has now been assigned to individual faults, the background seismicity of many zones has been reduced.

Overall, earthquake hazard has increased for sites located close to an active fault, and decreased for sites further from an active fault.

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