The 1959 Berridale NSW Earthquake Revisited

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Abstract: An earthquake on 18 May 1959 caused widespread but minor damage in the epicentral region around Berridale NSW as far as 40km in the direction of Cooma, and was felt out to a distance of 200km. The strong shaking is reviewed, the original assigned intensities have been re-discovered and an isoseismal map plotted with the spot intensities. More than 20 aftershocks were recorded but not in a typical aftershock pattern. The epicentre location, aftershocks and focal mechanism are examined to suggest that the Barneys Range Fault rather than the Berridale Fault or Crackenback Fault was the causative fault. We conclude that, contrary to published reports, the earthquake was not associated with the filling of nearby Lake Eucumbene. The earthquake history of the region is reviewed to establish the seismicity context and as a basis for educating journalists, a constant role for seismologists given the rapid turnover of media personnel.

Introduction

The largest earthquake in NSW since European settlement badly damaged Newcastle in 1989 and resulted in 13 deaths and a $1.3 billion damage bill. The magnitude of the earthquake was assessed at M5.6, virtually the same size as several earlier earthquakes in the State such as those near Dalton in 1934 and 1949, Robertson - Bowral in 1961 and Picton in 1973, none of which caused loss of life or substantial damage. The 1959 Berridale earthquake, was not much smaller at magnitude M5.3. It caused widespread minor damage as far away as Cooma.

In 2011 a week-long cluster of small earthquakes was recorded, near Berridale. The two events above magnitude 2.2 were felt by residents of Berridale which is about 2km from the Berridale Fault. News media personnel contacted by the author were surprised and claimed no knowledge of past earthquakes being felt in Cooma though as recently as April 1989 the town was shaken by a magnitude M3.7 earthquake near Jindabyne (McCue, 1996).

There are many large ancient faults mapped in the Snowy Mountains area of NSW, all of them capable of a much larger earthquake were these active faults, and were they to rupture from one end to the other. The earthquake at Newcastle occurred below the Sydney Basin in Lachlan Foldbelt basement rock and the fault rupture area, ~3km^2, was too small to propagate to the surface so the causative fault cannot be identified. The same is true of the 1961 and 1973 Bowral and Picton earthquakes. However, the causative fault for the 1959 Berridale earthquake, whilst contentious, may be more obvious with publication, post-earthquake, of a geological map of Kosciuszko National Park showing the faults (Wyborn, et al., 1990), and acceptance of the claimed epicentre location accuracy and computed focal depth.

Newspaper accounts of historical earthquakes in the Monaro up to 1960

The author’s records, and newspaper accounts retrieved using TROVE from the National Library, are summarised below showing that the Monaro has a long history of seismicity extending back towards 1840 when Cooma was first surveyed by Europeans, well back before the Snowy Scheme was commenced in 1949.

Below is a list of reported earthquakes, the first in 1869, and there are bound to be more.

1869 On the night of the 18th and 19th July a slight shock of earthquake was felt at Kiandra in the Snowy Mountains to the south {Empire (Sydney) 11 August 1869, p2}.

1878 COOMA. Tuesday 5.15 p.m. A shock of an earthquake which lasted some moments was felt at noon on Sunday. The Roman Catholic Church shook and the lamps clattered. It was also felt at Buckley's Crossing (author: Dalgety) and Adaminaby. Raining steadily and likely to continue {Queanbeyan Age, Wednesday 6 February 1878, p1}.

1885 On Wednesday morning between 11 o’clock and noon, a sharp shock of an earthquake was felt in Cooma, accompanied by a rumbling noise which lasted some 10 or 15 seconds at least. In the hotels and chemist shops, the bottles on the shelves shook, several of them being knocked off their perches. The shock travelled in an easterly and westerly direction and we learn that it was simultaneously felt at Wambrook, Adaminaby and Kiandra {Cooma Monaro Express, Saturday 24 January 1885}.

1897 Shock of earthquake at Cooma, N.S.W. on Saturday. {The Mercury Tuesday 9 March 1897 p2}.

1902 A distinct shock of earthquake, lasting 10 minutes, was felt Adaminaby on Wednesday night (Queanbeyan Age, Wednesday 22 October 1902, p2).

1910 EARTHQUAKE IN THE SNOWY MOUNTAINS A correspondent at Adaminaby telegraphs:- "This (Wednesday) morning at 11.59 a severe shock of earthquake was experienced here, and from information to hand it appears to have traversed the whole of the Snowy Mountains district, from Kosciusko to Rhine Falls. The shock resembled an immense field of artillery fired simultaneously, with distant rumblings of thunder lasting about, in all, five seconds. It was a very still, bitterly cold morning, with heavy mists."

Earth Tremors at Cooma. Three distinct shocks of earthquake were felt here today between noon and half-past 3 o'clock. None of the tremors was violent but the vibration was distinctly felt, accompanied by a rumbling noise, on each occasion {SMH Thursday 2 June 1910, p7}.

SHOCKS OF EARTHQUAKE COOMA. Monday. In connection with the recent shocks of earthquake, which were felt in Cooma and on the Snowy Mountains, a local resident has pointed out that there have been very few shocks of any severity in past years. One occurred in January, 1884, another, the heaviest known, in 1897, when a continuous motion was felt for three-quarters of an hour, followed by lighter tremors {SMH Tuesday 7 June 1910, p9}.

1959 WORST TREMOR IN MEMORY CRACKS WALLS DISRUPTS POWER. A severe earth tremor rocked the Monaro for up to 30 seconds on Monday afternoon. Women fled from their homes and people left shops all over the district as the rumbling tremor shook buildings to their foundations. Power supply in the whole of Monaro County Council area was cut off when electrical equipment supplying the district was upset (Cooma Monaro Express, Wednesday May 20 1959, p1}.

The tremor shook the whole region, from Albury to Wagga to Canberra, and down the coast from Narooma to Cann River.

The proprietor of the Berridale Hotel (Mr Bob Farmer) said the tremor had cracked the front wall of the hotel in the lounge room. ‘The wall was split right across, and up and down’. Plaster had fallen all through the hotel. ‘It felt as if a bomb had hit the town’ he said.

Many people were badly frightened in Cooma. There were many reports in the town of fallen plaster, crockery and wall ornaments. Walls of buildings were cracked by the tremor. At the ‘Express’ office a one-ton linotype swayed on its base and two-foot thick stone walls were cracked. The tremor shook away part of a chimney at Permewan Wright’s, while displayed fruit was shaken from its stand at Fullerton’s. Motorists at the time said the sensation in their cars was like a loose wheel or a flat tyre.

Considerable damage also occurred in the home of Mr and Mrs A W Mould at Middlingbank, about 15 miles from Berridale. Almost every window in the house had been cracked. A great deal of plaster had been brought down and a number of ornaments had also been broken.

18 April 1989 Operators of the Blue Cow ski resort rushed to the end of the Skitube fearing that the train had crashed through the end barrier, such was the jolt and noise in the office that accompanied the earthquake. Reports of shaking were phoned into the Bureau of Mineral Resources from as far as Mallacoota and Canberra but no damage was reported anywhere. Engineers in the Geehi tunnel reported feeling the earthquake as did a road construction gang at Bunyan, south of Cooma.

Reports of the January 1884 earthquake mentioned in the SMH of 7 June 1910 have not been found in contemporary newspapers but the search continues (perhaps the local resident was confused about the year and meant January 1885). Earthquakes have obviously been happening in the Snowy Mountains since Europeans arrived to write about them. It is obvious from the geology they were happening in the several million years beforehand when a similar crustal stress regime prevailed as today.

Distant earthquakes were also felt in Cooma including a small earthquake near Bega on 17 January 1912 and a large earthquake on 26 January 1892 off NE Tasmania:

1892 A shock of earthquake was felt yesterday morning in the Kiama, Jervis Bay, Cooma, and Pambula districts. It was heaviest at Kiama, where it lasted about 20 seconds. A sharp shock of earthquake was felt about the same time in the Callingmee Ranges, about 14 miles from Taralgon, Victoria {Sydney Morning Herald, Thursday 28 January 1892, p5}.

Isoseismal maps have been compiled from such reports for three of the earthquakes. Those of 1989 and 1959 are useful for calibrating the magnitudes of earthquakes that occurred prior to seismographs being deployed, such as that of 1885.

The lesson to be taken from this history is that earthquakes will continue into the future in the Monaro region and with a growing population and greater investment in infrastructure, we should expect some damage. Modern building practices may also exacerbate the risk with timber being replaced by un-reinforced masonry as a housing material. Modern earth and rock fill dams are fairly resilient in earthquakes, integrated concrete dams have yet to be so rigorously tested. Few if any electrical switchyards have been designed for significant shaking so widespread power outages should also be expected unless retrofit action is taken in the meantime.

The 1959 earthquake review is meant as a wake up call to local government councils, media and land owners in the Monaro. Now is a good time to revise their risk assessments.

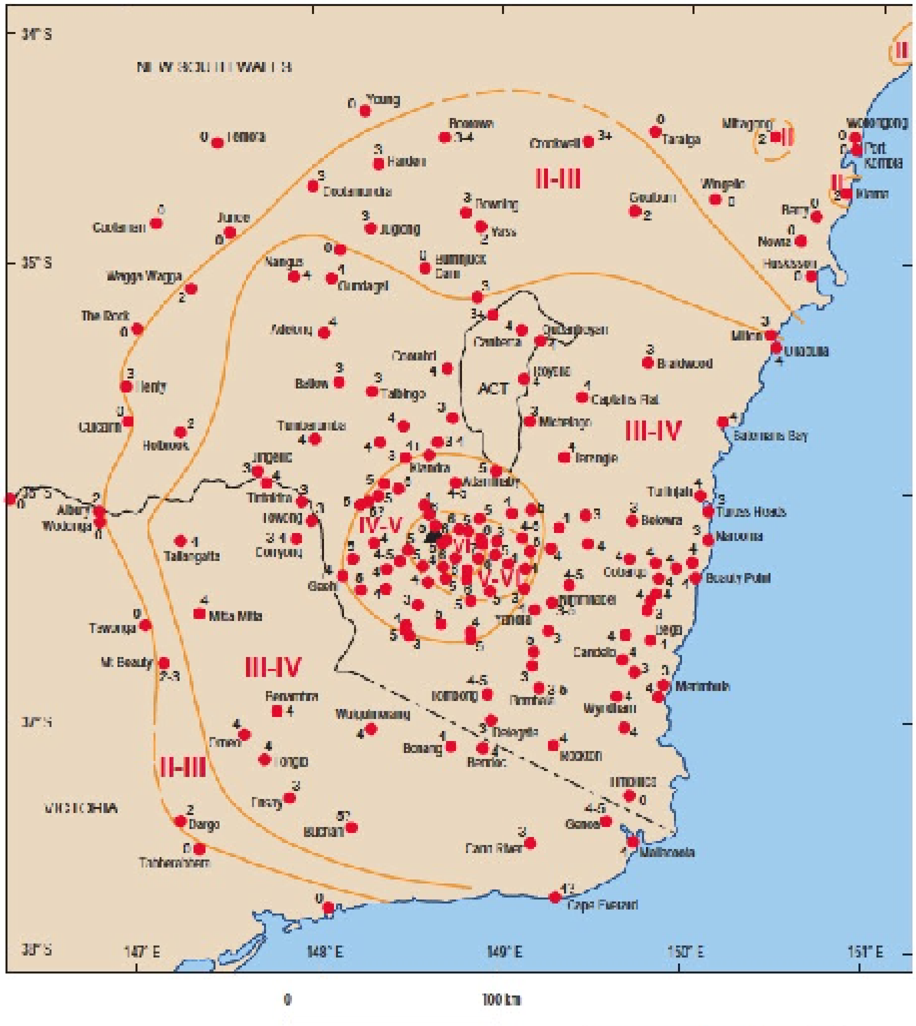
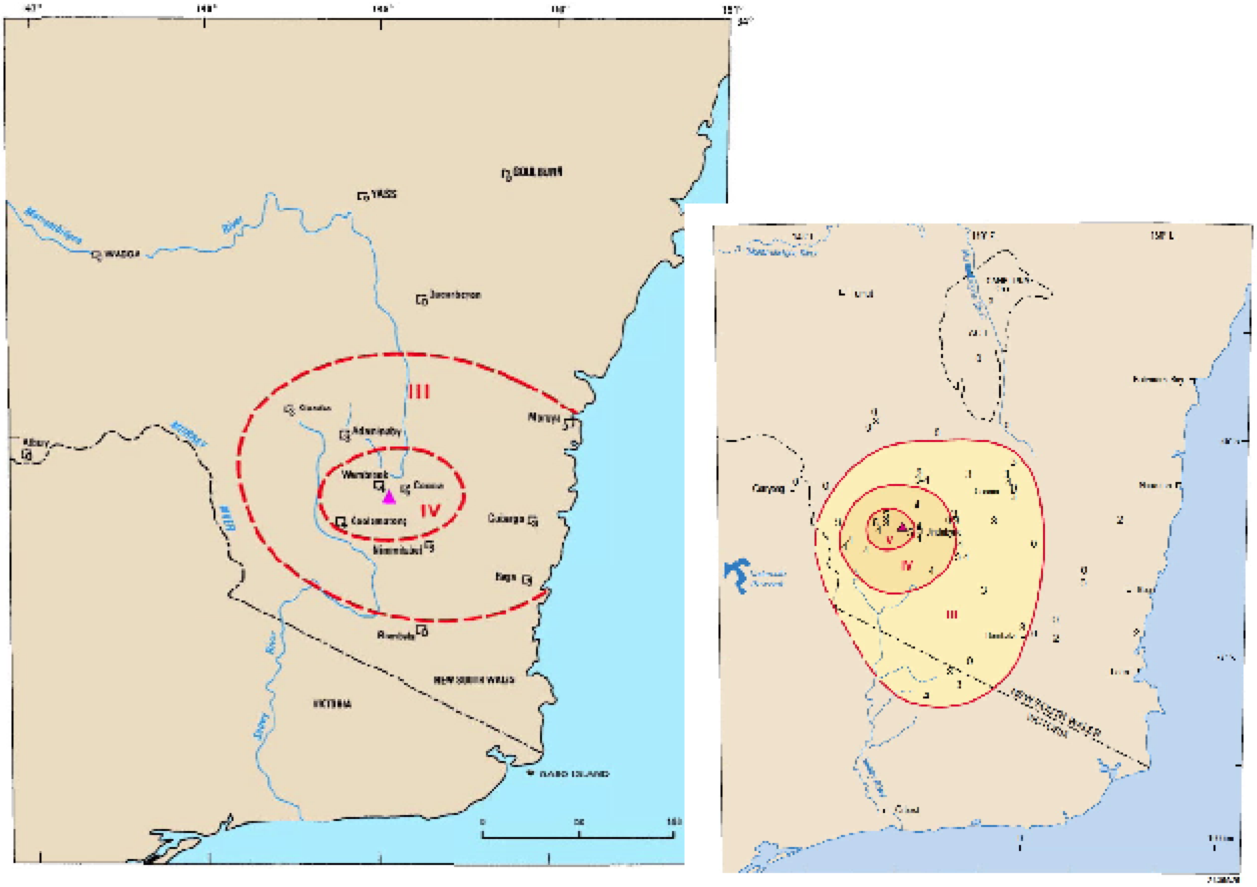


Figure 1 Isoseismal Map of the Berridale NSW earthquake, 18 May 1959. Following the discovery of the original hand-plotted map (with intensities) a few years ago in Cooma, this revised map was compiled to replace the map in the BMR Atlas of Isoseismal Map (Everingham & others, 1982) which had contours but no spot intensities.

Few Australian isoseismal maps have as many points as this one and the modern collection method of relying on web addressed forms will result in few ‘not felts’ reports, which are important to record. Seismologists in the business of creating these useful maps should back up their internet data collection methods with on ground surveys or phone calls, in the near-field region of high intensities and the far field at the detection threshold.



Figures 2&3 Isoseismal maps of the 21 January 1885 (left) and 18 April 1989 (right) earthquakes, at about the same scale. The 1989 earthquake near Jindabyne was measured at magnitude 3.7.

Magnitude frequency relation for NSW

The geological record attests to major magnitude ~M7 earthquakes having occurred in NSW and the Monaro in the Recent geological past. The consensus belief amongst practicing seismologists in Australia today is that the maximum earthquake likely to occur in Australia would have a magnitude of about 7.5 (Mmax). The largest actually observed (measured) was an earthquake in 1906 with a revised magnitude of 7.2, located off the west coast of Western Australia (Doyle and others, 1968).

The recorded history of annual maximum earthquakes in NSW is plotted in figure 4 below. A linear relationship fitted to the 1975-2010 period, overlain on the observations since the Riverview Seismographic Observatory was established in 1909 in Sydney, seems to be a good fit from magnitude 3 up to magnitude 5.6, the largest earthquake observed to 2011.

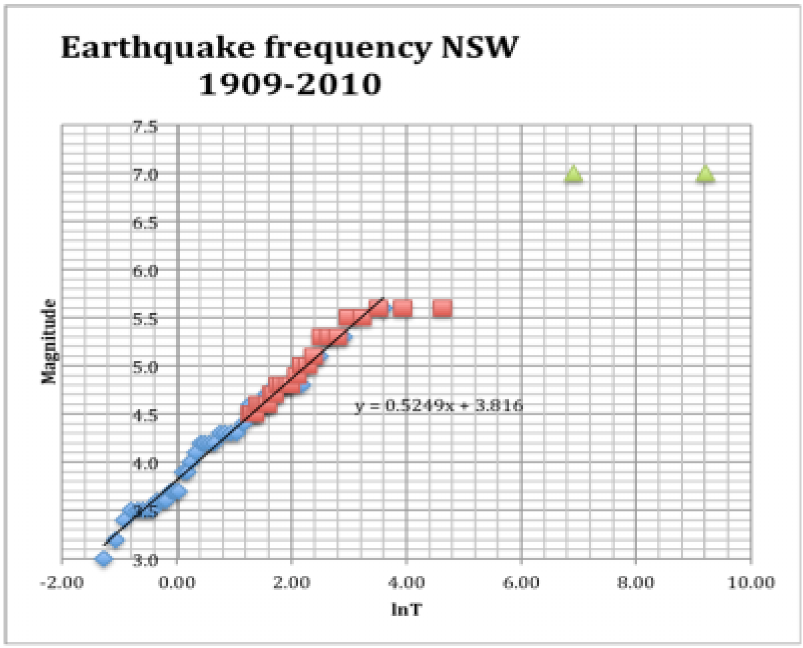


Figure 4 Magnitude M vs the natural log of return period T where the blue symbols represent data in the period 1975-2010, M≥3, the red symbols 1909-2010, M≥4.5, and the green symbols estimates only of the range of the probable recurrence interval for a magnitude 7 earthquake from paleoseismology constraints.

Here I have used a Type 1 Extreme Value distribution to estimate return periods because it seems to fit the observations quite well. Previously, with a much shorter sample period, I had adopted a type 3 distribution (McCue, 1978), allowing a comparison of the two sets of results. The linear trendline in Figure 4 is fitted just to the post-1974 data (the blue diamonds), during which time there was coverage down to magnitude 3 in most of the state. The history of larger earthquakes recorded since 1909 agrees well with the recent data.

The equation of best fit on the graph (x = lnT, T=1/N and y = M) can be transformed to

Log N = 3.19 – 0.83M

where T is the return period of a magnitude M earthquake and M≤5.6.

From this equation we deduce that the once-per-year event has a magnitude of about 3.8 (3.8), the 10-year event magnitude 5.0 (5.1) and the 100-year event magnitude 6.2 (6.0). The numbers in brackets are the magnitudes determined in the earlier study for the same return period.

From this 102 year recorded data sample we could surmise that NSW residents are lucky not to have experienced their 100 year earthquake. The period of European settlement of significant parts of NSW dates back to the 1880s when towns such as Broken Hill and Bourke were founded. We are reasonably sure that no large earthquake (M≥6) has occurred in at least the last 130 years in NSW.

Reservoir Induced Seismicity In Australia

Reservoir induced seismicity is seismic activity caused by humans building large dams then filling them with water. Not every large dam triggers seismic activity and not every large dam is instrumented to ensure that such activity is detected. It is thought that the mechanism for triggering such earthquakes is either (i) that the weight of water increases the normal stress or (ii) that water seeping into fractures and faults under the dams reduces the effective stress across them, and in either case brings the underlying faults to the point of failure which would not have happened otherwise.

Of the notable examples worldwide, a magnitude 6.3 earthquake near Koyna in western India (~300km SE of Bombay) is the most widely cited. Within four years of the commencement of reservoir filling, the area around the Koyna Dam experienced a large earthquake on 10 December 1967, and many aftershocks. It is reported that 177 people were killed when their masonry buildings collapsed and more than 2000 were injured with 50,000 made homeless. The concrete gravity dam was cracked but remained functional.

Australian dams that are reported to have experienced reservoir induced seismicity include Eucumbene (Gibson, 1998), Talbingo (Muirhead, 1981) and Pindari dams in NSW, Gordon dam in Tasmania, Dartmouth and Thompson dams in Victoria (Allen and others, 2000), and Argyle Dam in WA.

The Eucumbene Reservoir began filling in 1958, with a gross capacity of 4.8km^3 of water and a maximum depth of 116.1m. By the end of 1959 water had risen to the outskirts of Old Adaminaby so the reservoir was well below capacity when an earthquake of magnitude ML 5.3 occurred about 20 km south of the dam on 18 May 1959. Lake Eucumbene finally reached capacity in 1973. In the following 50 years at least 300 locatable earthquakes occurred up to 30km south of the dam in the same region as the 1959 epicentre near Berridale.

Discussion: The 1959 earthquake in relation to Eucumbene Dam and mapped faults

Moye (1955) classified the faults in the Snowy Mountains area into two groups:
(a) Old faults developed during the crustal disturbances which caused the repeated folding of the strata. Many of such faults are "healed" and the crushed rock cemented by later deposition of silica and other minerals. Some are not healed.
(b) Faults associated with the warping and uneven elevation of the area during the movements of uplift in the Tertiary period. During this period some of the old faults were reactivated, and new ones formed.
Few faults are exposed at the surface. Many have been inferred from study of air photos and surface mapping and proved by drilling or trenching; and many have been found in exploratory and construction tunnels, road cuttings and other excavations.

So, some of the faults have been 'healed', some rejuvenated. Only earthquakes on the fault can differentiate the active faults from the inactive ones. Some assessment of the probability of rejuvenation can be made by considering the type of fault (ie whether a thrust, normal or strike-slip fault) and its orientation in the current stress field which measurements indicate is characterised by a principal stress acting in a NW/SE direction.

The computed earthquake epicentre was very well located (± 1km claimed), with four seismographs within 50km (the closest 20km) and well distributed around it (Cleary and others, 1964). It occurred almost 20km south of the dam (red dot Figure 5) almost equidistant between the dam and Berridale, and at a mid-crustal depth of about 15km.

There were no foreshocks, and in the 6 months following the mainshock very few aftershocks occurred which is most unusual for reservoir triggered seismicity. Hundreds or thousands of small aftershocks is the norm. There were only 5 very small events, the largest of them magnitude 2.5, and these early aftershocks with the mainshock are aligned in a roughly NNE direction, at a high angle to the Berridale Fault.

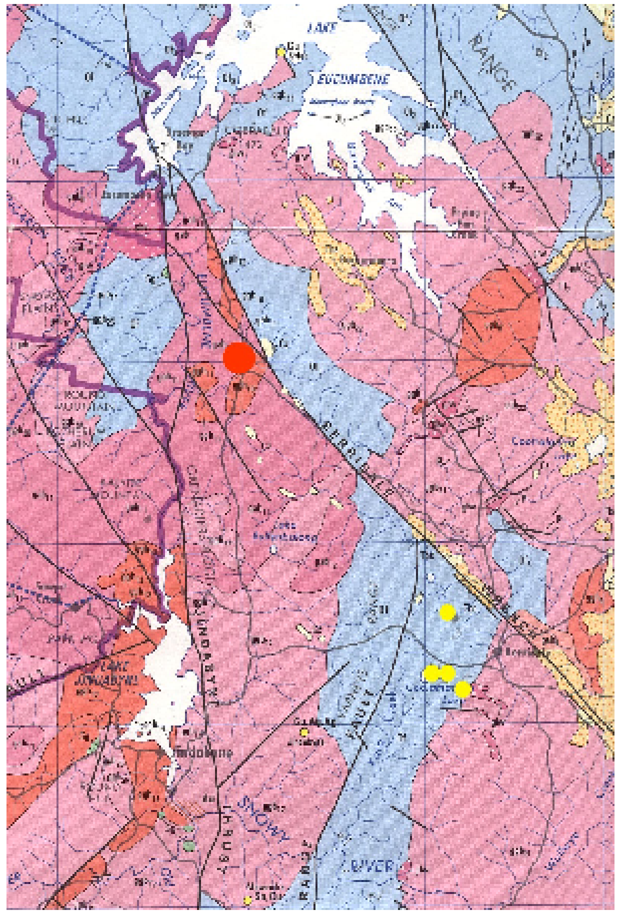


Figure 5 The geology near Berridale NSW, centre-right of map and Lake Eucumbene (Wyborn & others, 1990). The red dot is the 1959 earthquake epicenter, the yellow dots the 4 larger earthquakes in a swarm in 2011.

One of the nodal planes of the focal mechanism also trends in approximately this NNE direction (Cleary & others, 1964, replotted by Denham & others, 1981) as shown in figure 6.

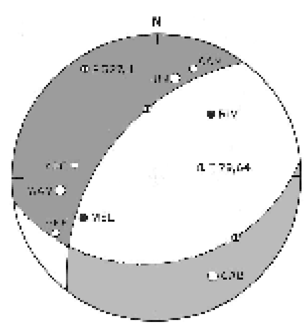


Figure 6 Focal mechanism for the 18 May 1959 Berridale earthquake.

The mechanism, a thrust, is not what one would expect on the Berridale Fault which is a left-lateral strike-slip fault, both nodal planes are at a high angle to the Berridale Fault (as pointed out by Bock and Denham, 1983).

The aftershock epicentres are co-linear with the Barneys Range Fault, a link-fault between the Jindabyne Thrust and Berridale Wrench Fault, and the earthquake focus is near the intersection of the two faults in the focal region around 15 km depth. It is much more likely that the earthquake occurred on the Barneys Range Fault, which the morphology suggests is a splinter fault off the west-dipping

Jindabyne Thrust Fault, than an unnamed fault conjugate to the Jindabyne Thrust Fault favoured by Bock and Denham (1983). Since earthquakes have occurred on or near several of the large mapped faults here (within the uncertainties in the hypocenter locations), the whole set of inter-connected faults should be considered active, for hazard assessment purposes.

The 20km distance of the epicenter downstream from the Eucumbene Dam, the lack of an extensive aftershock sequence coupled with the trend of those that did occur in the first 6 months at an acute angle to the Berridale Fault, together with a history of earthquakes in the region over the previous 90 years, cast significant doubt as to any causal relationship between reservoir filling and earthquake.

Acknowledgment

GA, ANU and Snowy Hydro (formerly SMHEA) made data available for this research. I am especially grateful to Laurie and Maureen Fletcher, Louvain, Rocky Plains, who first discussed the earthquake with the author many years ago. Laurie felt the shaking whilst outside in Adaminaby and got home to find their stone meat-shed at Louvain badly cracked in the earthquake.

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