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The West Tasman Sea (Flinders Island) earthquake of 14 September 1946

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The largest southeastern Australian earthquake this century occurred in the West Tasman Sea, 100 km east of Flinders Island, at 1948 UTC on 14 September 1946. Its epicentre was at 39.97°S, 149.35°E and its Richter magnitude ML 6.0. It was felt strongly throughout Tasmania and Gippsland, Victoria, and caused minor damage in Launceston. The isoseismal map of the earthquake is consistent with lower strong ground motion attenuation in Tasmania than in mainland southeastern Australia, and the macroseismic effects suggest amplification of seismic shaking by Tertiary lake sediments in Hobart and Launceston.

Introduction

On 14 September 1946 at 1948 UTC (Co-ordinated Universal Time) (5.48 am local time on 15 September) a large earthquake occurred in the West Tasman Sea, northeast of Tasmania, which was felt strongly and caused some minor damage. The event, which also woke people in Victoria, is the largest this century in the West Tasman Sea Zone (Michael-Leiba & Gaull, 1989). Around 2000 events in the zone were felt in northeastern Tasmania or the islands off the coast from 1883 to 1892 (Ripper, 1963). Several had magnitudes exceeding ML 6.0, were felt in Victoria and did damage in Launceston (Michael-Leiba, 1989a). This century, activity in the zone has declined and only four events have had magnitudes of ML 5.0 or greater (Michael-Leiba & Gaull, 1989). The earthquake of 14 September 1946 is not only the largest in the Zone since 26 January 1892, but also appears to be the highest magnitude event in southeastern Australia this century.

Epicentral parameters

In the International Seismological Summary for 1946 (British Association Seismological Committee, IUGG, 1955), the epicentre is given as 40.2°S, 149.0°E. This location was based on readings from 43 stations of which 29 had P and/or S residuals of 5 s or less. The maximum gap in azimuth of seismographs relative to the epicentre was 139°. The closest station used in the location was Riverview (Sydney, NSW) at an epicentral distance of 6.6°. The event was very widely recorded, and P and/or S residuals of 5 s or less were obtained from stations as far away as Riverside (California, USA), Moscow (Russia), Rome (Italy), Paris (France) and Toledo (Spain), the most distant seismograph with an epicentral distance of 159°. The P residuals were 3 s or less at the four nearest stations: Riverview, Brisbane, Christchurch and Wellington, as were the S residuals at Riverview, Christchurch, Wellington and Auckland. The origin time was 19 hr 48 min 42 s.

The earthquake was also recorded on the Milne-Shaw E-W component seismograph at Melbourne (Victoria), the closest station, at an epicentral distance of 4.0°, so a relocation was done using program EQLOCL written by staff of the Seismology Research Centre, Royal Melbourne Institute of Technology, with a southeastern NSW crustal model out to 600 km with a spline fit to the Jeffreys-Bullen tables. The program uses P and S waves only for distances beyond about 1000 km and up to 101°. The P and S arrival times from Melbourne, Riverview, Christchurch and Wellington, the Brisbane P, and the Auckland and New Delhi S were used in the location. The Brisbane S, Auckland P and Suva P and S were deferred because their residuals were greater than 10 s. The epicentral coordinates obtained were 40.07°S, 149.30°E, and the residuals of the readings used were 4 s or less. The origin time was 19 hr 48 min 49 s with an uncertainty of 13 s.

The two epicentres are very close, ours being 29 km ENE of the International Seismological Summary's. However, the maximum gap in azimuth relative to the epicentre is 193° for the seven stations used in the EQLOCL location. The International Seismological Summary's epicentre lies within the error ellipse of this solution for which the uncertainty in easting is 30 km, in northing 56 km and in origin time 13 s.

A relocation was also done with the Melbourne arrival times and ISS data having residuals of 5 s or less. The program was written by Ken Muirhead (AGSO) and uses Jeffreys-Bullen tables. The epicentre, based on 25 stations with a gap of 169 and maximum residual 5.3 s, is (39.97±0.21)°S, (149.35±0.15)°E and the origin time is 19 hr 48 min (50.1±0.6) s. The Muirhead epicentre is 39 km northeast of the International Seismological Summary epicentre. All three epicentres are shown in Figure 1 but we prefer the Muirhead solution.

Magnitude

The Riverview College Observatory (RIV) Seismological Bulletin recorded a maximum vertical ground amplitude for SN of 16 μm at a period of 2.5 s. This gives a magnitude ML 5.5 using Michael-Leiba & Malafant's (1992) southeastern Australian attenuation.

The Milne-Shaw seismograph at Melbourne (MEL) recorded a maximum trace amplitude of 70.8 mm (zero-to-peak) at a period of 1.5 s. The magnification of the instrument at this period is 250, giving a ground motion amplitude of 283 μm and a magnitude ML 6.4 using Michael-Leiba & Malafant's (1992) attenuation.

The duration of the vibrations on the Milne-Shaw measured from the onset to when the oscillations on the record decay to double the background level is 2914 s, which gives a duration magnitude MD 6.2, using the formula $MD = 2.1 \log\tau + 0.0009\Delta - 1.52$, where τ(s) is duration and Δ(km) is distance. This formula is used routinely by the Australian Seismological Centre.

From the isoseismal map (Fig. 1). the intensity-based magnitudes measured from the MM III (McCue, 1980) and IV (Michael-Leiba, 1989b) isoseismals are ML(I) 6.1 and ML(IV) 6.4. The MM III and IV isoseismals are close together. This may be because the former is poorly

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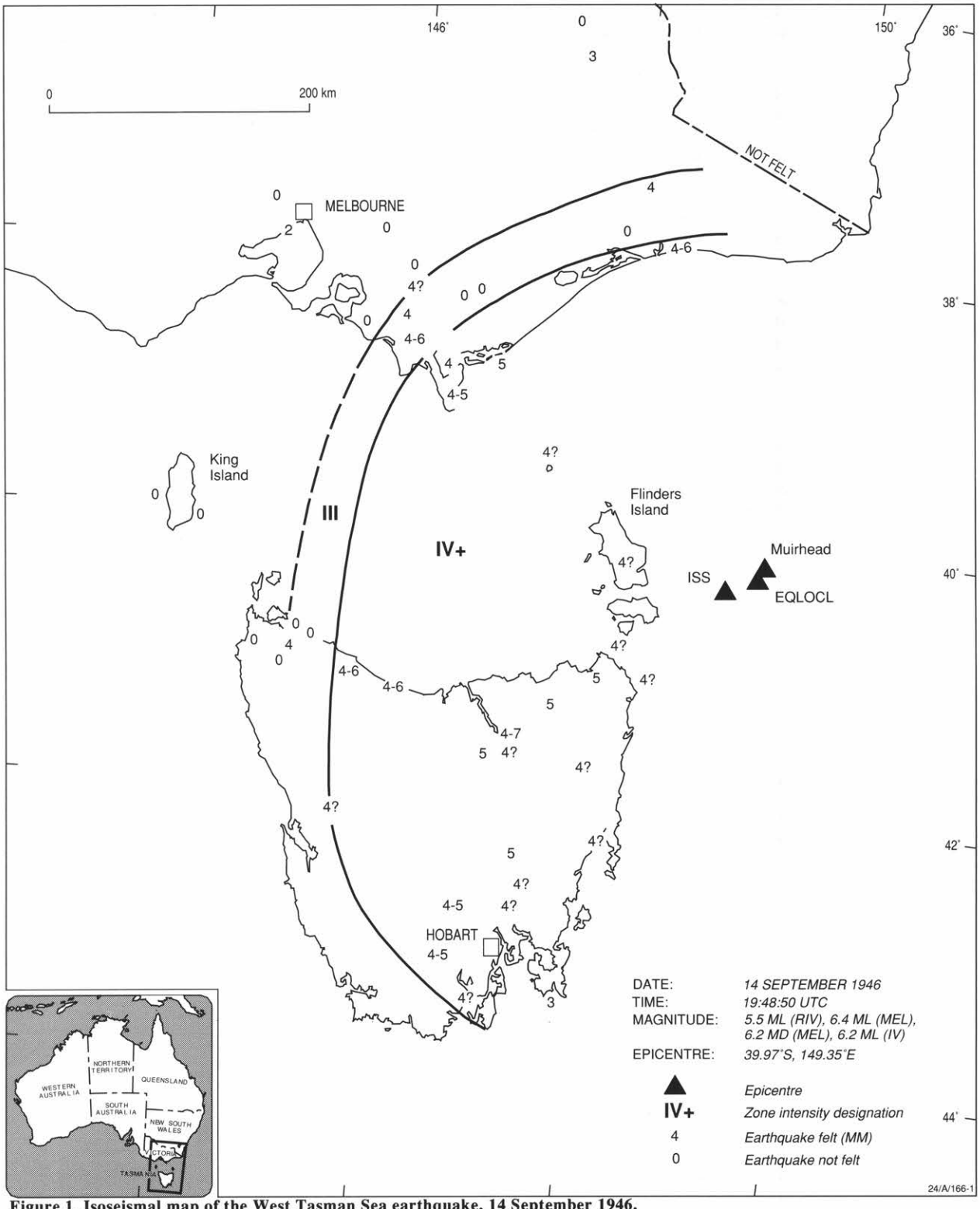

Figure 1. Isoseismal map of the West Tasman Sea earthquake, 14 September 1946.
The three alternative epicentres obtained by the ISS, the EQLOCL program and the Muirhead program are shown. The Muirhead epicentre is preferred.

constrained due to the early hour of the earthquake and the absence of felt reports from Bass Strait and the Southern Ocean, and the Tasmanian part of the latter is uncertain because of the lack of detail in some of the felt reports in newspapers. In the Discussion, we propose that ground motion attenuation may be lower in Tasmania than in mainland southeastern Australia. This could mean that the magnitude was overestimated, so separate measurements were made using only the Victorian part of the isoseismals. These gave magnitudes of ML(I) 6.1 and ML(IV) 6.2. As the MM IV isoseismal is better constrained in Victoria, ML(IV) 6.2 is the preferred intensity-based magnitude. The

figure of 6.1 obtained for ML(I) is probably a minimum value.

The preferred estimates of the local magnitude are ML 5.5 (RIV), ML 6.4 (MEL), MD 6.2 (MEL) and ML(IV) 6.2. Their mean is (6.1±0.4) but, as the first three were rounded up, we assign a magnitude ML 6.0 to the earthquake. This makes it the largest event recorded in southeastern Australia this century. The second largest ones were of magnitude ML 5.6 and included the 1989 Newcastle earthquake. The other three were in the West Tasman Sea (1929), Dalton-Gunning, NSW (1934) and Robertson-Bowral, NSW (1961).

Macroseismic effects

The isoseismal map (Fig. 1) and the description of the effects of the earthquake are based on contemporary newspaper reports and lighthouse logs. The sources are The Mercury (Hobart), The Examiner (Launceston), The Advocate (Burnie), The Circular Head Chronicle, The King Island News, North Eastern Advertiser (northeast Tasmania), Foster Mirror, Omeo Standard, Morwell Advertiser, Leongatha Echo, The Star (Moe), Upper Murray & Mitta Herald, The Powlett Express (Wonthaggi), The Warburton Mail, The Warragul Guardian, The Sydney Morning Herald, The Age (Melbourne), The Argus (Melbourne), and lighthouse logs from Swan Island, Maatsuyker Island, Low Head, Eddystone, Cape Sorell, and Tasman Island.

The earthquake was felt strongly throughout Tasmania and in Gippsland, Victoria. It was accompanied by a low rumbling sound. The shaking was variously estimated to have lasted between 20 and 50 seconds.

Where intensities have been marked with a question mark in Figure 1, the newspaper reports were not specific about the felt effects.

As with other large events in the West Tasman Sea (Michael-Leiba, 1989a), the highest intensities and most damage were recorded in Launceston, where the earthquake broke windows and crockery and cracked plaster in some buildings. Two hotels were affected. Wireless poles swayed and buildings were seen to rock.

The Mercury of 17 September 1946 said of the Rosevears Hotel in Launceston that

> It would be necessary to plaster walls split by the shock, but foundations were not seriously affected ... The front entrance was damaged, part of the staircase torn away, and the bannister broken from the wall. Four rooms were damaged and some crystal goblets broken.

The Examiner of 16 September 1946 stated that:

> The only injury reported in Launceston was suffered by John Tipping, whose left leg was bruised when plaster from the ceiling above his bed in the Court House Hotel, Paterson Street, fell on him during the tremor. The fallen plaster left a bare patch on the ceiling 5ft. long and 18in. wide. The piece which struck Tipping was 18in. long and a foot wide and weighed about 40 lb. He said yesterday that he owed his escape from serious injury to the fact that he was awake when the tremor began and saw the plaster falling. He jumped from the bed and the plaster struck him only a glancing blow. Mr. E. Lee, who occupies the next room to Tipping, said 'If the plaster had struck Tipping a direct blow, it would certainly have broken his leg. I carried the piece which hit him down from the bed to the hotel yard. It weighed about 40lb. The weight falling from the 9ft. high ceiling would be sufficient to kill a man if it hit him on the head'. A woman living at 96 York St. was thrown out of bed but was uninjured by the fall.
>
> The tremor caused one of the relay bells at the Launceston fire station to ring. Fireman A. Neville, one of the four men on duty at the time, said the station shook so violently he thought it was 'falling to bits.' He said the trestle beds in the dormitory at the station were shot back and forth by the force of the tremor.

In Hobart, there were reports of four distinct rocking motions from north to south, gradually increasing in intensity. Although many parents said that children were terrified when the houses shook, there was no damage reported.

In the North West Coast district of Tasmania, household crockery and fragile ornaments which fell during the earthquake were broken.

In northeastern Tasmania, the North Eastern Advertiser of 17 September 1946 noted that the tremor 'was probably the most severe disturbance recorded in the district, but only slight damage to property has been reported'. There was mention of houses rocking and the earthquake sounding like loud rumbling.

The event is said to have woken thousands of people in Gippsland, Victoria, where it was felt from Orbost to Leongatha. In Foster, the earthquake had caused crockery to fall off shelves in some houses and had made the police station grandfather clock, which was not going, chime. A few ornaments and crockery items in houses were damaged in Orbost where the tremor was accompanied by a roaring sound. No building damage was reported in Gippsland.

The earthquake was also felt slightly at Mitta Mitta in northeastern Victoria and at the breakwater pier off Williamstown, and the 18 m high Harbour Trust observation tower at the entrance to Victoria Dock, just southwest of Melbourne city, shook violently twice as though a large ship had bumped the wharf heavily. There were no other Melbourne reports. These are the northernmost and westernmost locations in Victoria which reported that the earthquake was felt.

Discussion

Figure 1 and the above reports show that the most damage was experienced in Launceston, 210 km from the epicentre. Launceston has been damaged also by earthquakes in the West Tasman Sea on 13 July 1884, 12 May 1885, 26 January 1892 (Michael-Leiba, 1989) and 28 December 1929 (UTC dates). Michael-Leiba & Gaull (1989) attribute the relatively high level of earthquake damage there to local site effects due to ground motion amplification by Tertiary lake sediments up to 200 m thick. A similar situation appears to exist in Hobart. The Advocate of 16 September 1946 reported that 'in Hobart the tremor was most marked in the Sandy Bay area and least of all at North Hobart and New Town'. It is significant that Sandy Bay is predominantly underlain by Tertiary lake sediments whereas at North Hobart and New Town the foundation is mainly Triassic quartz sandstone or lithic arkose and lutite

(Leaman, 1972).

The MM IV isoseismal in Figure 1 appears to be asymmetric. One possible explanation is that the epicentre is further north than it should be, due to a paucity of seismographs to the south. However, none of the instrumental locations of events in the West Tasman Sea Zone has put an epicentre far enough south to make the contour symmetrical. The other possibility is that the ground motion attenuation in Tasmania is less than in eastern Victoria.

Michael-Leiba (1992) derived a Tasmanian attenuation formula:

$$I = 4.94 + 1.45\ ML - 3.61 \log R$$

where I is Modified Mercalli intensity, R km is hypocentral distance (assuming a focal depth of 10 km), and ML is Richter magnitude using Michael-Leiba & Malafant's (1992) formula. The attenuation is based on 29 measurements on isoseismal maps of 14 Tasmanian earthquakes, 12 of which were not West Tasman Sea events. Michael-Leiba (1992) noted that this attenuation gives intensity estimates 0.6–0.7 intensity units higher than Gaull & others' (1990) southeastern Australian formula modified for the new ML scale (Michael-Leiba & Malafant, 1992, in press). The modified southeastern Australian formula is:

$$I = 4.35 + 1.5\ ML - 3.91 \log R$$

Thus, our preferred explanation for the asymmetry in the MM IV isoseismal is that Tasmanian attenuation is indeed lower.

Conclusions

The International Seismological Summary gives the epicentral coordinates of the earthquake as 40.2°S, 149.0°E, and the origin time as 19 hr 48 min 42 s. A relocation using arrivals from 25 stations including Melbourne gives an epicentre at 39.97°S, 149.35°E and an origin time of 19 hr 48 min 50 s. This is our preferred solution. It is only 39 km northeast of the International Seismological Summary epicentre which is remarkably good considering that the International Seismological Summary had no computers for earthquake location.

Based on amplitude readings from the Riverview and Melbourne seismograms, the duration on the latter, and our preferred intensity-based magnitude, we assign a Richter magnitude ML 6.0 to the event. This makes it the largest earthquake in southeastern Australia this century.

The 1946 event is in the West Tasman Sea Zone (Michael-Leiba & Gaull, 1989), the site of high seismic activity late last century. The earthquake is the largest in the zone since 26 January 1892. While activity there has declined this century, the occurrence of a magnitude 6.0 event in 1946 suggests that similar earthquakes may occur in the zone in future.

Macroseismic observations at Launceston and Hobart suggest that local site effects are due to amplification by Tertiary lake sediments.

The asymmetry in the MM IV isoseismal may be a result of lower strong ground motion attenuation in Tasmania.

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