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The Lithgow earthquake of 13 February 1985: macroseismic effects

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The Lithgow earthquake of magnitude ML 4.3, which took place on 13 February 1985, was the largest earthquake to have occurred in the Blue Mountains region of New South Wales since the Kurrajong earthquake of 1919. It caused minor damage in Lithgow and Wallerawang and was felt as far away as Parkes and Dubbo, 200 km from the epicentre. The total damage was estimated at approximately $65 000. Macroseismic and instrumental evidence suggests that, for this earthquake, the attenuation to the northeast in and under the Sydney Basin was much greater than the attenuation to the southwest through the Lachlan Fold Belt.

Hypocentral parameters

On 13 February 1985 at 08 h 01 min 23 s UT (BMR solution) an earthquake of magnitude ML 4.3 occurred beneath Lithgow, New South Wales. This was the largest event to have occurred in the Blue Mountains region since the ML 4.6 Kurrajong earthquake on 15 August 1919 (Cotton, 1921; Everingham & others, 1982). Although the Kurrajong event was larger, the Lithgow earthquake was felt with greater intensity in the epicentral region.

Using Herrin travel-time tables (Herrin & others, 1968) and an earthquake location program written by B.A. Bolt and modified by M. Landisman and L. Sykes, the epicentre was determined from 30 P-wave arrivals as being at 33.49° S, 150.18° E. Because no seismograph stations were operating close (<20 km) to the epicentre, it was not possible to estimate the depth from the travel-times. However, from the relationship $I_0 - I = 3\log(1 + h^2/r^2)$ Båth, 1979, p.127), where I_0 is the maximum intensity and I the intensity at radius r, the depth, h, was calculated to be 7 km. If this depth is a reasonable estimate, the hypocentre was situated beneath the Sydney Basin, which is about 0.7 km thick at Lithgow (Bembrick, 1980).

The Richter magnitude (ML) was determined using Richter's standard distance factors extended by Eiby & Muir (1961). Distance corrections (Drake, 1974) were applied to compensate for the difference between the attenuation in southern California and southeastern Australia. Where measurement was made on a vertical component record, 0.15 was added to the ML values, because Richter's attenuation factors were derived for horizontal seismographs, which record larger amplitudes than equivalent vertical instruments. Table 1 shows the values of ML obtained for six stations. The scatter is discussed in another section. The mean value of ML is 4.3±0.2, where the error term is the standard error of the mean.

Table 1. Magnitude of Lithgow earthquake

Station	Distance (degrees)	Azimuth (degrees)	ML
COO	3.2	27.1	3.8
RIV	0.9	113.0	3.9
STK	7.4	280.1	4.2
CMS	4.2	297.3	4.3
TOO	5.6	221.8	4.7
BFD	7.2	237.3	4.7
			Mean 4.30 ± 0.2

Macroseismic effects

The isoseismal map shown in Figure 1 is based on 129 reports (65 felt and 64 not felt) from questionnaires, verbal reports, and photographs of damage in Lithgow (Figs. 2, 3, 4). Included in this data set are 36 replies to questionnaires distributed by the Sydney Metropolitan Water, Sewerage and Drainage Board (L. McQueen and A. Preston, personal communication).

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Sheryl Taylor of television station Channel 9 (Sydney) inspected the damage in Lithgow the day after the earthquake. She saw several partly demolished chimneys and broken windows, a shop in which beams 25 cm thick had shifted, a house in which the footings and front step had moved, and fresh cracks in walls and the widening of existing cracks in some buildings. Don Kipp of the *Lithgow Mercury* said that the earthquake had been felt severely all over Lithgow, bringing people running out into the streets. Objects fell off shelves in many parts of the city. The intensity was less in the underground mines than on the surface, because the amplitudes of both body and surface waves are greater at a free surface.

In a well-built wooden single-storey house on compact ground in Wallerawang (7 km northwest of Lithgow), about the lower 60 cm of the walls were made of brick on concrete footings (Mr. Lang, personal communication). The earthquake produced a vertical crack, approximately 1 mm wide, that passed through eight courses of bricks and mortar of the lower wall, one brick length from a corner of the house. In another single-storey house on compact level ground, the earthquake caused narrow vertical cracks each running through two or three bricks and the intervening mortar of the lower wall, which was of poor quality brickwork. Fibro walls in other houses suffered 1 cm wide cracks running from the ceiling to half way down the wall at an angle of about 30° to the vertical (Mrs Bird, personal communication).

In Wallerawang power station, the earthquake caused new cracks in a previously cracked wall on the first floor. The new cracks were in a part of the wall that was not already cracked (John Forest, personal communication). Both vertical and diagonal cracking occurred (Figs. 5, 6). A diagonal crack also occurred in the well-built brick external wall of the power station at ground floor level. The crack is 2.5-3.0 m long and decreases from about 1.5 mm wide at the top to approximately 0.5 mm at the lower end, petering out about 1.3 m above ground level. It generally follows the mortar, but passes diagonally through several bricks. The main generator at the power station tripped, owing to physical shaking of the float-type switch (Bucholtz relay) on the transformer.

The maximum intensity was assessed as VII on the Modified Mercalli scale, 1956 version (Richter, 1958), at both Lithgow and Wallerawang.

Several reports of anomalous damage (Fig. 1) were received from Bathurst some time after the earthquake. These were attributed to the February 13 event. One claim of moderate damage to brick and plaster in all rooms of a single storey, well-built brick house on compact level ground was paid by an insurance company (Joan Renshaw, personal communication). The apparently high intensities in some

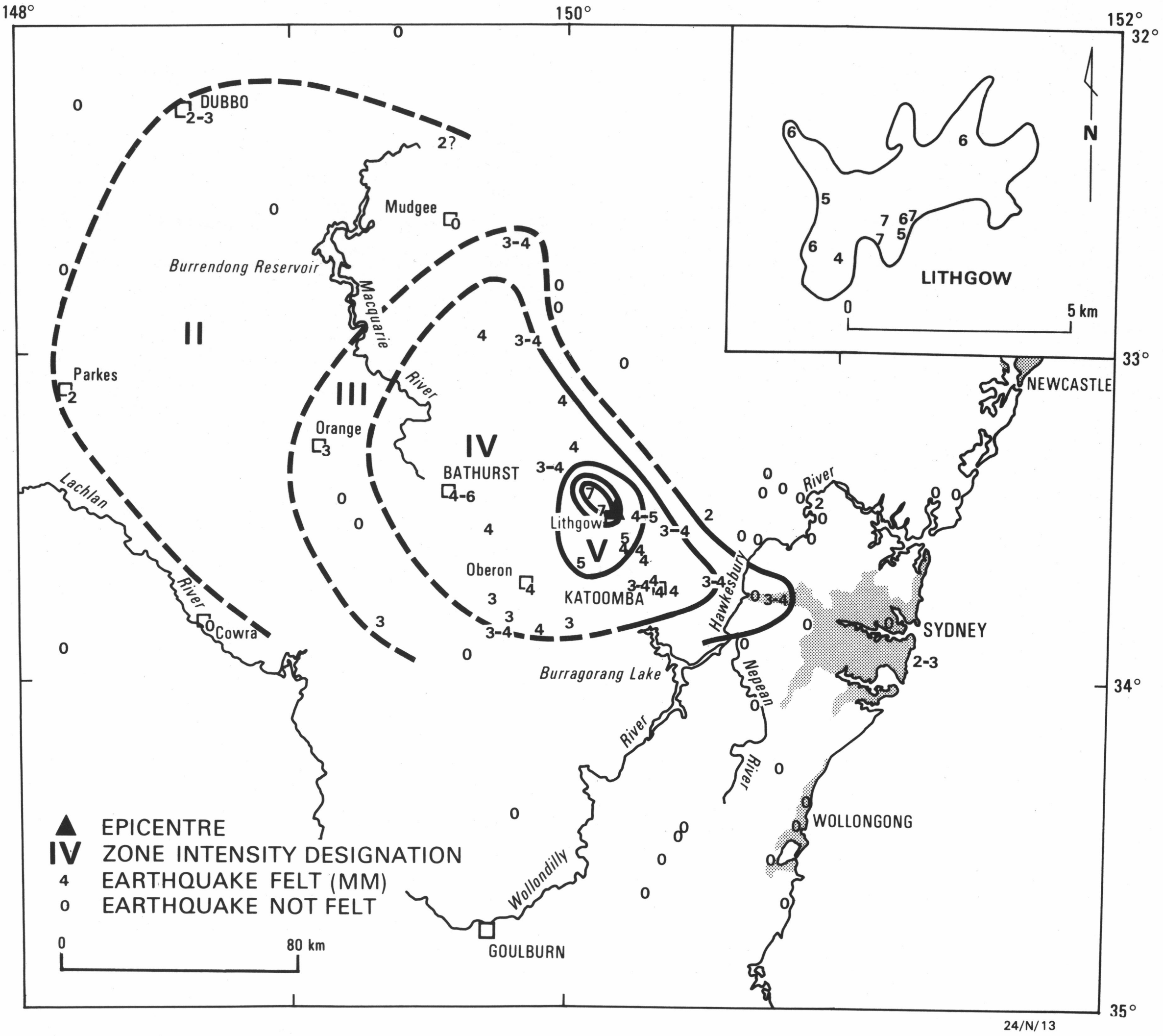

Figure 1. Isoseismal map of the Lithgow earthquake of 13 February 1985.
Intensities were determined with reference to the Modified Mercalli scale, 1956 version (Richter, 1958). The inset shows an enlargement of the Lithgow urban area.

Figure 2. Chimney in Lithgow, collapsed at the roofline because of the earthquake.
It used to be the same height as the chimney in the background (A. Churchill—personal communication). Photograph by A. Churchill, Rembrandt Photographics, Lithgow—commissioned by BMR.

Figure 3. Earthquake-damaged chimney in Lithgow.
Photograph by A. Churchill, Rembrandt Photographics, Lithgow—commissioned by BMR.

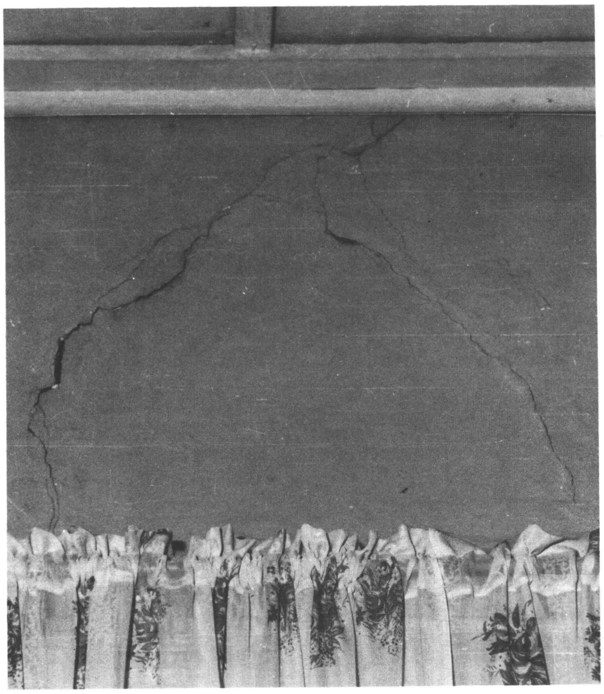

Figure 4. Cracking in a wall of a house in Lithgow.
The crack on the left was caused by the earthquake; the one on the right was slightly re-opened (A. Churchill—personal communication). Photograph by A. Churchill, Rembrandt Photographs, Lithgow—commissioned by BMR.

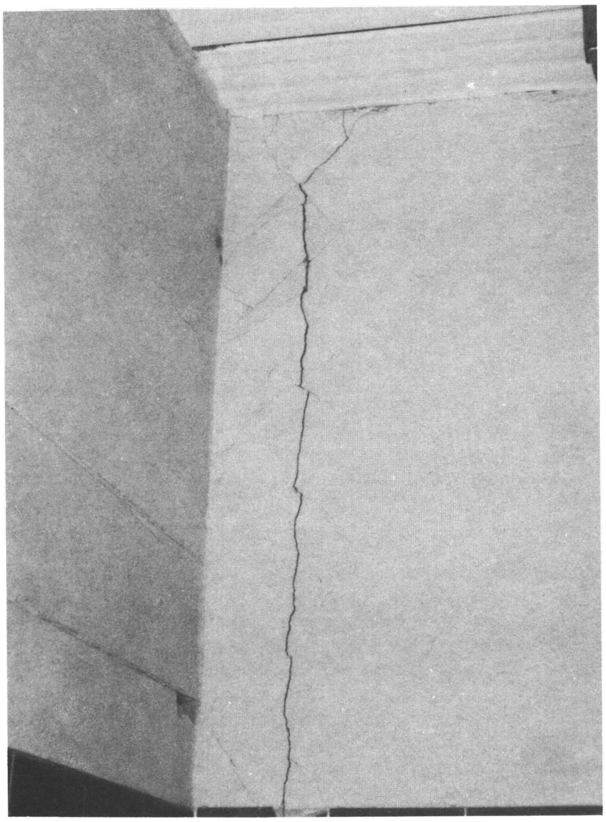

Figure 5. Vertical and diagonal cracking on the first floor of Wallerawang Power Station.
The 'X' crack near the top of the picture is caused by failure in tension along both diagonals during horizontal oscillations. Photograph by J. Forest, Wallerawang Power Station.

parts of Bathurst are difficult to explain. However, the earthquake was felt as far away as Parkes and Dubbo, 200 km from the epicentre.

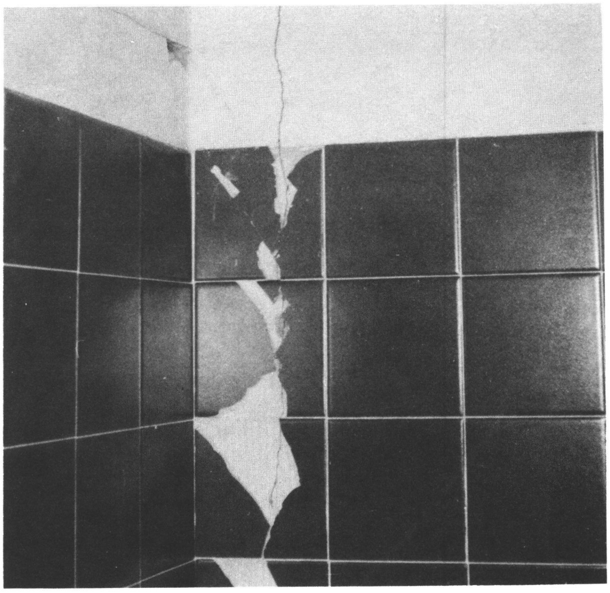

Figure 6. The vertical crack in Figure 5 continues down into the tiles in the lower part of the wall.
Photograph by J. Forest, Wallerawang Power Station.

The earthquake is estimated to have caused about $65 000 worth of damage. (This was deduced from information provided by the major insurance companies, and allowing for the excess and for the fact that not all houses were insured with these companies).

Anisotropy of attenuation

The isoseismals of the Lithgow earthquake are very asymmetrical, suggesting that the attenuation east of the epicentre is much greater than to the west. Figure 7 shows the positions of the Sydney Basin and the Lachlan Fold Belt and indicates that, for this earthquake, the attenuation of ground shaking was much greater in and under the Sydney Basin than through the Lachlan Fold Belt.

Figure 8 shows a comparison of the attenuation in intensity along segments QP and QR of line PQR in Figure 7. This line was chosen because it provides the best coverage of intensity data for the Sydney Basin and Lachlan Fold Belt (see Fig. 1). Nevertheless, there is a great deal of uncertainty about the positions of some of the isoseismals. This is indicated by error bars in Figure 8. Despite the uncertainty, the attenuation is clearly greater along section QR to the east than along QP to the west. If the position of the epicentre on the isoseismal map (Cotton, 1921) of the Kurrajong earthquake is correct, the rather meagre data from that event suggest that a similar, though less pronounced trend may have been observed.

The scatter of magnitudes in Table 1 also suggests anistropy of attenuation. There appears to be relatively high attenuation in and under the Sydney Basin (relatively low values of ML at RIV and COO) compared to the west (CMS and STK) and southwest (TOO and BFD). The attenuation to the southwest appears to be particularly low. Part of the differences in the attenuation may be due to the radiation pattern caused by the faulting mechanism. However, as this is unknown, it cannot be allowed for.

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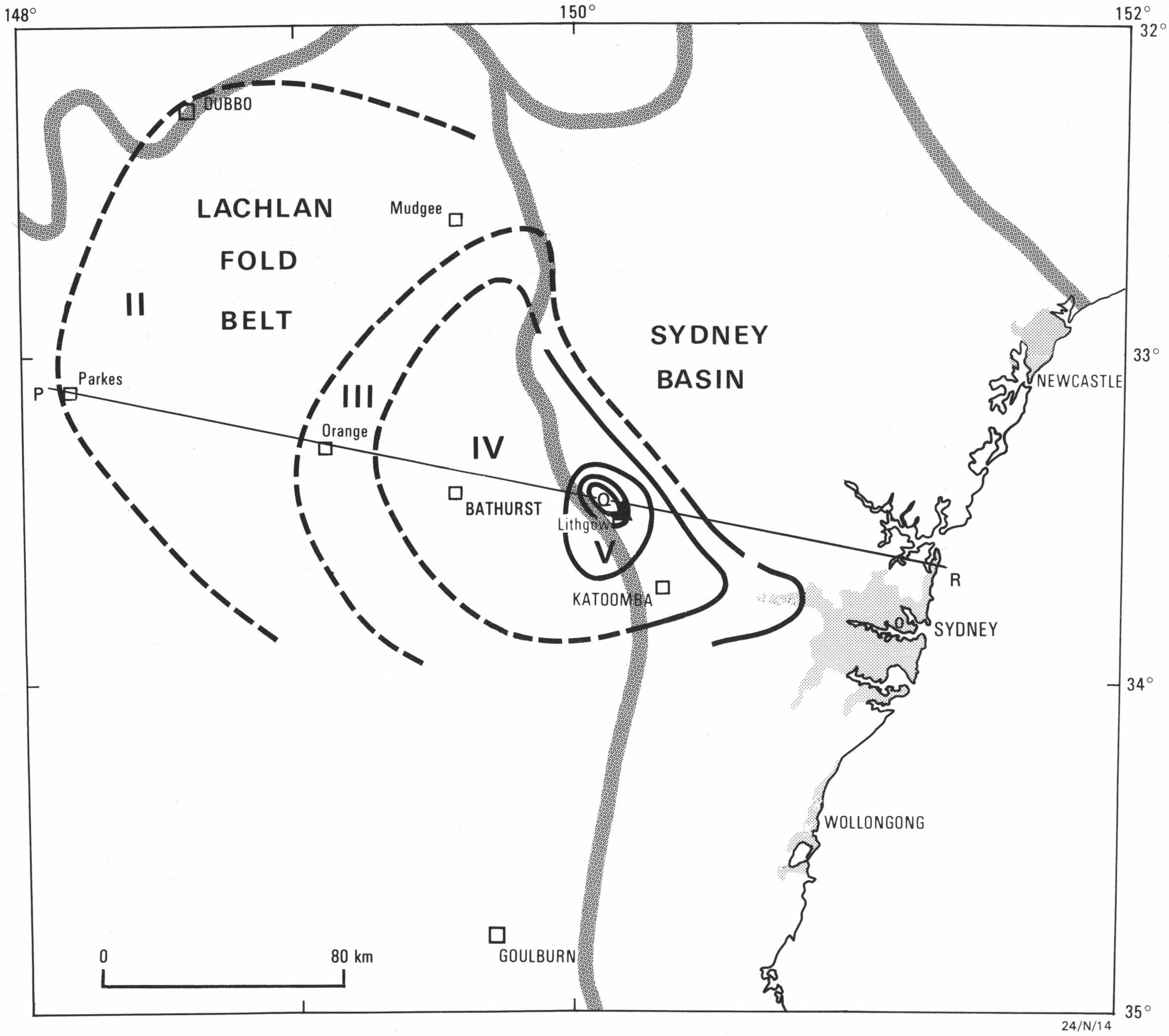

Figure 7. Relationship of the isoseismals to the major structural elements of the area.

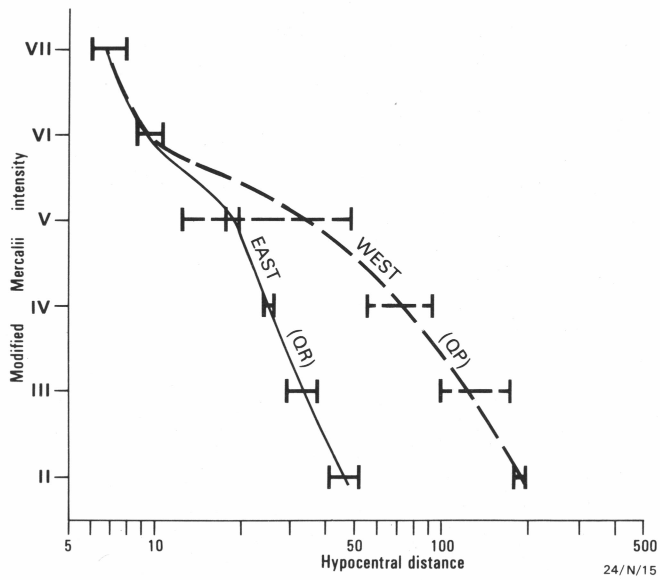

Figure 8. Attenuation curves for the intensity along segments PQ (to the west) and QR (to the east) of line PQR in Figure 7.

effects of the Lithgow earthquake. We acknowledge the help of A. Bullock, T. Jones, P. Eversons, M. Douch, and L. Hodgson, all of BMR, in collecting information related to the earthquake. We thank B. Gaull and K. McCue for critically reviewing the manuscript, P. Burrell and L. Creamer for typing it, and C. Fitzgerald for drafting the figures.

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