

THE LAKE COLERIDGE EARTHQUAKES OF 1946

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SUMMARY

The magnitude (ML) 6.2 earthquake of 1946 June 26d 12h 34m 39s.7 U.T., with an epicentre at $43^{\circ}.18S$ $171^{\circ}.68E$, near Lake Coleridge, is the largest known event in the Central Seismic Region of New Zealand. It was felt over the greater part of the South Island, and caused minor structural damage to homesteads in the Upper Rakaia basin, and at the Lake Coleridge hydro-electric power station. There were also numerous landslides and changes to watercourses. It was preceded by two foreshocks and followed by numerous aftershocks, the largest of which had a magnitude of 5.8. These persisted until the end of 1949.

INTRODUCTION

The Central Seismic Region of New Zealand is less active than either the Main or the Fiordland Region. There are fewer earthquakes, and the largest known ones are smaller. Periods of activity alternate with periods of almost complete quiescence, and the shocks are concentrated now in one and now in another part of the Region (Eiby 1970, 1971). Although it would be possible to suggest subdivisions based upon these concentrations, or upon the geological structure, the number of shocks in the less active parts of the region is so small that any such exercise would at best be only speculative. Indeed, the boundaries of the Region itself remain a few tens of kilometres in doubt.

Individual shocks discussed in this paper will be identified by the reference numbers assigned in the New Zealand Seismological Reports, which also contain details of the phase arrivals used in the epicentre determinations. The shock of magnitude 6.2 that occurred near Lake Coleridge on 1946 June 26 (Origin 46/91) was the largest earthquake with an epicentre indisputably within the Region since a seismograph was installed at Christchurch in 1901. Some early epicentres assigned to the so-called Arthur's Pass earthquake in 1929 lie in the Central Region. Reasons for believing the correct epicentre to lie in the Main Region are given by Eiby (1970). There are no historical records of earlier events of comparable size, but the Region has always been sparsely populated. In 1946 the Seismological (then the Dominion)

Observatory was prevented from making field-studies of the damage by the staffing difficulties that followed the war, and no connected account of the shock was published. In the course of a revision of instrumental data the importance of this earthquake became evident, and prompted this paper. It may be of some historical interest to note that newspapers in several different centres reported that "many people" attributed the shock to the effects of an atomic bomb reaching the Dominion.

INSTRUMENTAL DATA

The principal shock, at 12h 34m 39s.7 U.T. on 1946 June 26, was recorded at ten New Zealand stations, and at 55 stations in other parts of the world. It was assigned an epicentre at $43^{\circ}.18S$, $171^{\circ}.68E$ and a magnitude (ML) of 6.2. Details of phase arrivals at New Zealand stations will be found in the "New Zealand Seismological Report 1945-46-47" (Eiby 1983), and those at overseas stations in the International Seismological Summary. The two largest aftershocks were also recorded at stations outside New Zealand. The monthly Provisional Bulletins for 1946 and 1947 (P-172 et seq.) assign epicentres to numerous felt aftershocks, and to two foreshocks, but only a small number of these were based upon instrumental data. More than fifty of them, including one of the supposed foreshocks, depend only upon a single felt report, the shock being assumed to have the same epicentre as the main earthquake. Although many of these reported events are probably real, only those for which there are instrumental data are assigned numbered origins in the Report, the others being listed as "unconfirmed".

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Figure 1 shows the distribution of aftershock epicentres about that of the main

earthquake. With a few exceptions that can be attributed to uncertain location, the epicentres of the aftershocks lie within a roughly circular region about 35 km across, with its centre close to the northern end of Lake Coleridge. The epicentre of the principal shock lies just within the eastern boundary of the area.

Table 1 includes the reference numbers, origin times, and epicentres of all instrumentally recorded shocks in and near the region on the day of the main shock and the following day; and of the only two shocks of magnitude 5 and above to occur before the end of the year. The letter F following the magnitude indicates that the shock was reported felt. All solutions were restricted to a conventional depth of 12 km.

MACROSEISMIC DATA

Figure 2 shows Modified Mercalli isoseismals for the principal shock, at 12h 34m 39s.7 U.T., based on questionnaires returned by the Observatory's regular reporters together with information contained in the newspapers of South Canterbury and Westland, an unpublished two-page report to the Acting-Director of the Dominion Observatory by Mr H.F. Baird of the Magnetic Survey, Christchurch; the log book of the Lake Coleridge power station, and the records of the Regional Engineer of the N.Z. Electricity Department, Christchurch. Mr Baird, who visited the Lake Coleridge district on 1946 July 23, was the only person with seismological training to visit the area at the time. He was unfortunately taken sick and forced to return before completing his inspection.

I visited the region from 1982 November 22-25, and began and ended my visit with two long interviews with Mr and Mrs R.E. Anderson of Darfield, who were living at Mt Algidus at the time of the shock. Mrs Anderson was able to add considerably to her

published account of the earthquake (Anderson 1963, pp142-4), and also to put me in touch with neighbours who have now moved from the district. At the places visited, it proved possible to identify repairs to earthquake damage, and to speak with people whose knowledge was gained from parents or close friends who were in the area at the time of the shock.

The main earthquake (Origin 46/91) was felt in most parts of the South Island, except for Fiordland and the northern parts of Marlborough. The distribution of felt intensity in the magnitude 5.8 aftershock on June 28 (Origin 46/115) was similar to that in the main shock, but reported intensities were in general about one degree less. Estimates of intensity are listed in the N.Z. Seismological Report (Eiby 1983), and details of the observed effects are summarised below.

Since the principal shock occurred half an hour after local midnight and in winter few people were awake, and there were no reports indicating intensities less than than MM-III. Except for an apparently anomalous report from Invercargill at a distance of 440 km., all places at which the shock was felt lie within 300 km. of the epicentre. No reports were received from places in the North Island. Press statements that it was felt in Wellington are references to the Observatory's instrumental recordings.

EFFECTS NEAR THE EPICENTRE

The most severely affected region is shown in Figure 3. The area of maximum intensity is roughly 50 km. across and includes Lake Coleridge and the confluences of the Harper, Wilberforce, and Mathias Rivers with the Rakaia. The Lake and the rivers lie in wide glaciated valleys whose floors are about 500 m. above sea-level. The surrounding ranges rise steeply to over 2 000 m., but glaciation has reduced the height of some of the dividing hills. The power station at

TABLE 1

Ref.	Date	Origin Time (U.T.)	Lat.	Long.	Mag.
46/90	Jun.26	12 13 12.5	43.44	171.44	4.3F
91	26	34 39.7	43.18	171.68	6.2F
92	26	53 51.6	43.32	171.31	4.7F
93	26	13 06 48.3	42.12	171.19	4.3F
94	26	16 54.0	43.24	171.55	4.1F
95	Jun.26	13 17 43.1	43.19	171.61	5.1F
96	26	28 12.6	42.06	172.62	3.5
97	26	29 54.0	43.11	171.41	3.9F
98	26	41 18.9	43.17	171.52	3.7F
99	26	14 15 43.5	42.85	170.65	4.4F
100	Jun.26	14 45 09.6	43.26	171.57	4.0F
101	26	15 42 29.2	43.15	171.37	4.4
102	26	16 30 29.3	42.04	171.22	3.8
103	26	22 18 33.3	43.32	171.56	4.3F
104	27	02 00 21.2	43.11	171.66	3.7
105	27	03 07 28.6	43.18	171.59	3.8
115	28	07 12 41.6	43.34	171.21	5.8F
125	30	21 07 37.6	43.19	171.31	5.1F

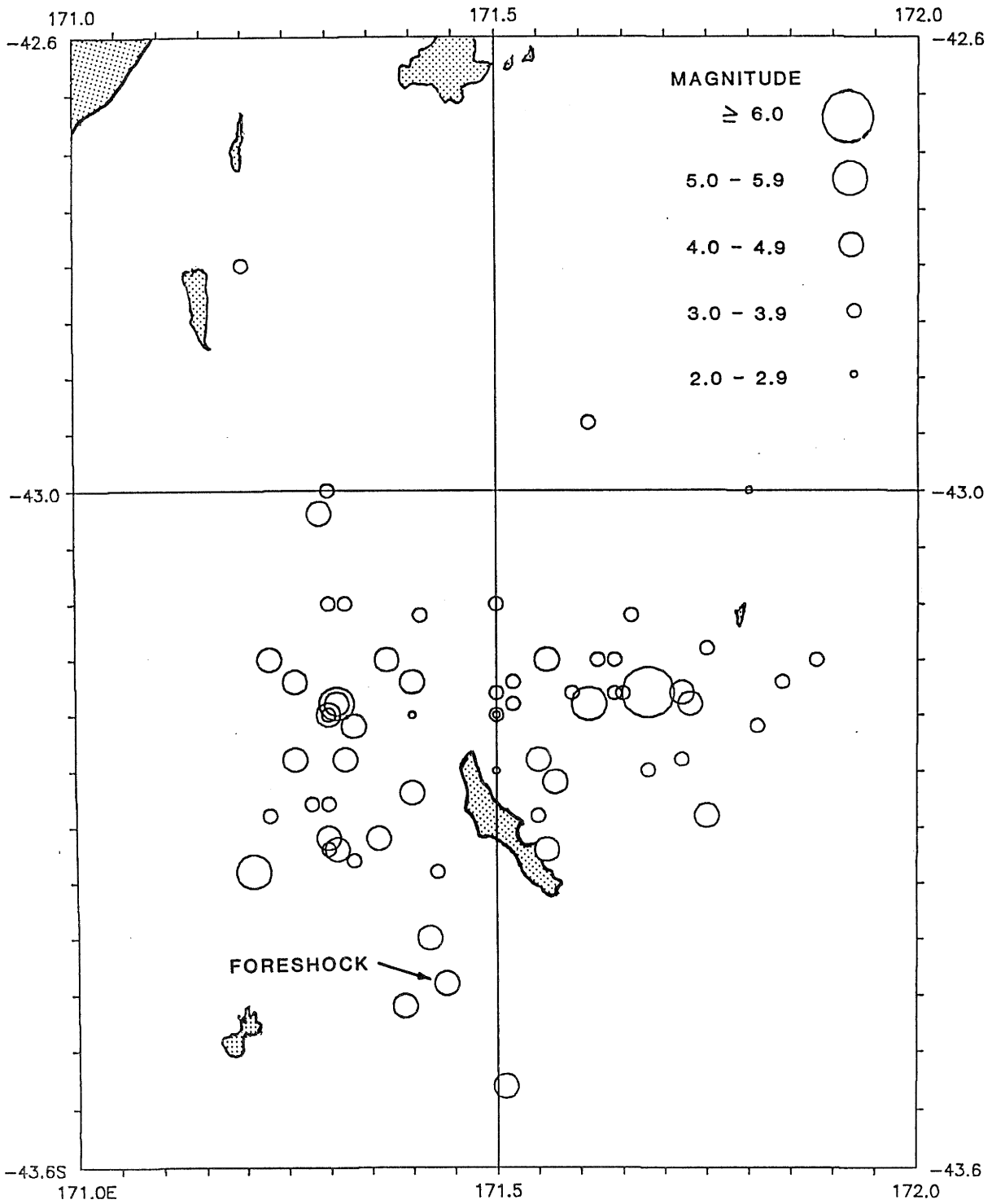


FIGURE 1. EPICENTRAL REGION OF THE LAKE COLERIDGE EARTHQUAKE, SHOWING THE RELATION OF FORESHOCK AND AFTERSHOCK EPICENTRES TO THAT OF THE MAIN SHOCK.

FIGURE 2. MODIFIED MERCALLI ISOSEISMALS FOR THE PRINCIPAL EARTHQUAKE ON 1946 JUNE 26 (Origin 46/091). IT HAS NOT BEEN POSSIBLE TO SHOW INDIVIDUAL OBSERVATIONS WITHIN THE MM-VII ISOSEISMAL ON THIS SCALE. THESE ARE SHOWN IN FIGURE 3.

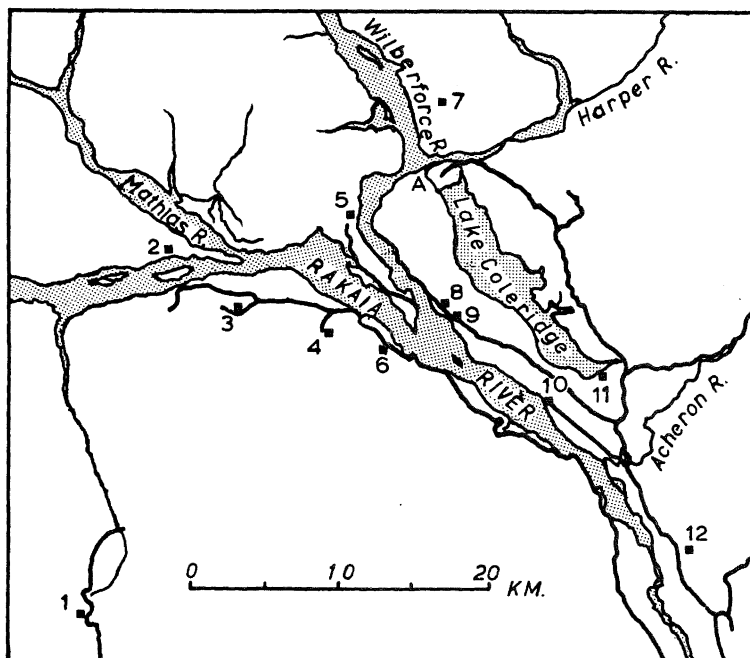
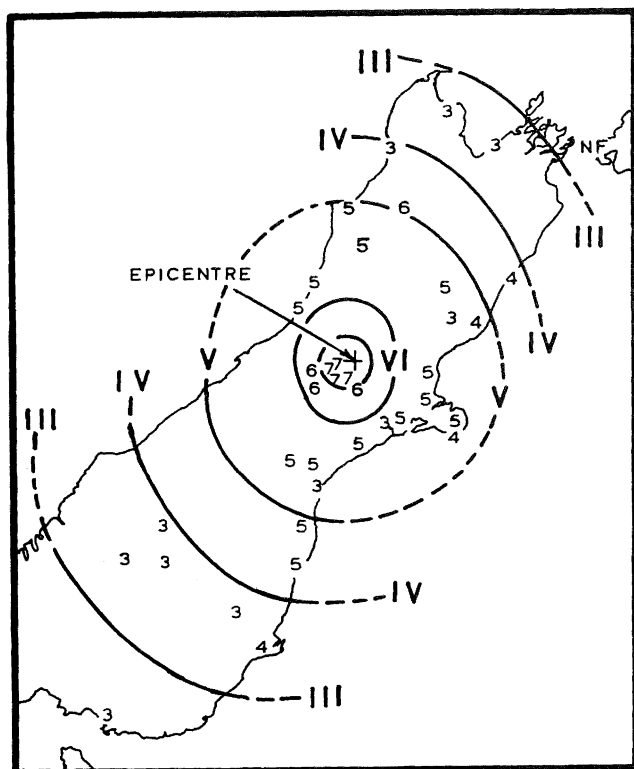


FIGURE 3. EPICENTRAL REGION, SHOWING PLACES NAMED IN THE TEXT. AN INTENSITY OF MM-VII WAS REPORTED EXCEPT AT PLACES WHERE A LESSER FIGURE FOLLOWS THE NAME.

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|--------------------|--------------------|
| 1. LAKE HERON (VI) | 7. GLENTHORNE |
| 2. MANUKA POINT | 8. MT OAKDEN |
| 3. DOUBLE HILL | 9. PEAK HILL (VI) |
| 4. GLENARIFFE | 10. POWER STATION |
| 5. MT ALGIDUS | 11. COLERIDGE (VI) |
| 6. GLENROCK | 12. SNOWDON (VI) |
| A. OUTLET SPILLWAY | |

Lake Coleridge is the only large building in the district, and the small village housing its workers is the only centre of population, though it is frequented by campers in the summer months, and there are more than a dozen sheep-stations.

Most of the farm buildings are wooden-framed and clad with weatherboards or corrugated iron, but at the time of the earthquake many of the older homesteads were at least in part of cob (rammed earth) construction, and over half a century old. All cob buildings were damaged in 1946, and none are known to have survived until now.

The maximum intensity reached was at least MM-VII. A literal reading of the intensity scale could perhaps be used to justify an estimate of MM-VIII, at least at those places on poorer ground, but allowance must be made for deficiencies of construction. When many of the farmsteads were built (or rather begun, for in many cases subsequent additions have become the major part of the structure), access to the upper Rakaia was difficult, with the result that river boulders were used for chimneys, fire-places, and foundations, and much of the construction was carried out by farm labour rather than by trained builders. The structures cannot be called poorly-built, but they are often unconventional in design, making it difficult to compare their seismic properties with those of buildings elsewhere. Time did not allow close enough inspection to determine with certainty which buildings stood upon old flood terraces, and which on more solid spurs of bedrock.

Extensive landslides occurred throughout the MM-VII area, and to a smaller extent in that of MM-VI. The country is steep, with impressive scree slopes, and many of the slides reported are undoubtedly movements of existing slips; but it is probable that new slips also occurred (Anderson 1963), indicating possible localised areas of MM-VIII.

In addition to structural damage and landslides, drainage patterns were changed, particularly in the neighbourhood of Mount Algidus and the Power Station.

Observations at particular localities are summarised below:

Mount Algidus

The homestead was a wooden-framed weatherboard structure and its chimneys were of reinforced concrete, with liners. These were undamaged. Much crockery was broken, and a piano crashed through a gibraltar-board wall. Farm buildings were mainly clad in corrugated iron, some with brick and some with concrete chimneys. These were shattered at the base, and in the case of the cookhouse were broken off at roof level. Brickwork around the large cast-iron range was shattered, and the adjoining brick bakers' oven made permanently unusable. One aftershock (presumably the strongest) threw water from the homestead water-tank (Anderson, pers. comm.). Press reports of the time tell of "tanks thrown a foot or two off their stand levels".

Changes to watercourses were very pronounced. Algidus Creek (also known as Titan Creek) never again carried the same volume of water; but the Andersons were unable to confirm alleged changes to Chimera (Jack's) Creek and thought that substantial change was unlikely. A running spring feeding a swampy area above the homestead ceased to overflow, and the swamp almost dried up. Another swampy area above the woolshed ceased to run, and became completely dry in dry seasons.

Mount Oakden

The present runholder, Mr Robertson, told me that the chimneys were twisted, but did not come down. There were many slips and shattered rock on the slopes of the Mount, which gave off a great deal of dust for the rest of the season. I understood Mr Robertson to have been a witness of the events he described, but the Andersons believed that he had not arrived until shortly after the earthquake. A letter from the Electricity Department appears to confirm this, but I believe that the Andersons could have been the source of that information.

Double Hill

The back part of the homestead, believed to have been of cob, collapsed.

Rakaia Gorge

A two-ton boulder was dislodged from the cutting above the bridge, and roads in the surrounding hill country were reported to be impassable. The driver of the mail truck reported that a bad slip at the Black Hill cutting had covered the road in thousands of tons of earth and rock, and that it had been necessary for him to drive the truck along the river-bed for more than a mile.

Glenrock and Glenariffe

The homestead at Glenrock lost every chimney, and many articles of crockery were broken, but Glenariffe was reported to have suffered little damage.

Lake Heron

The station manager described the shock as severe, though there had been little damage, but that there were many slips in the district. People were sleepless because of the aftershocks.

Manuka Point

A wooden house. The chimney in the shearers' quarters fell.

Glenthorne

The house was an old cob building on a sloping terrace of gravel and clay. It was twisted, and the chimneys fell. It had to be largely rebuilt.

Peak Hill

A wooden house; lost no chimneys.



FIGURE 4. THE HOMESTEAD AT SNOWDON. CHIMNEYS FELL, AND THE ORNAMENTAL COLUMNS OF THE VERANDA WERE RACKED SIDWAYS, BUT THERE WAS LITTLE STRUCTURAL DAMAGE.

Lake Coleridge Station

The Andersons knew of no damage, and believe that they would have heard of anything substantial.

Snowdon (Figure 4)

Chimneys fell in on themselves, and brickwork around the cooking range was damaged, but most damage was to plaster and not structural. This was described by Baird, but part of his description and his analysis of the causes is questionable. The repairs are still visible.

Lake Coleridge Power Station

This reinforced concrete building is in two sections of roughly equal size (Figures 5 and 6). One was part of the original construction in 1914, and the other was added in the late 1920s. The two parts of the turbine hall have the same roof line and wall alignment, but the level of the floors differs by two or three metres. Damage occurred where the two sections join, and at the junction with office and storage space to one side of the older portion. About 70 window panes were broken. These are old metal-framed windows about half a metre square, and spontaneous breakages and damage by wind are apparently fairly common. The concrete walls below the windows show many shrinkage or settlement cracks. There is nothing obviously tying the old and new sections together, and signs of relative movement in the past are apparent.

Power station reports held in the Christchurch District Office of the Electricity Department refer to damage to "concrete wing walls at the Lake outlet dam". This is a kind of spillway structure apparently designed to release water from the Lake to the Harper River. It has had a concrete "skirt" added at some subsequent time, and appears to be much lighter in construction than one would expect to find in such a structure today.

Damage to the electrical equipment does not appear to have been serious, though a power surge accompanied the earthquake and caused the breakers to trip. Pipelines were found to have moved a few inches. Twisted telephone lines had to be untangled, and a broken transformer bushing replaced.

Rockfalls caused anxiety at the Power Station. The Lake became discoloured, and was reported to have become increasingly so throughout most of July, "principally in the South East half, possibly as a result of under water slips". Late in the month it was "still somewhat discoloured", but the matter is not mentioned again. The Annual Report records that "slips and slumping occurred at a number of places more especially near the source of Whisky Creek, and various springs temporarily increased their volume and became muddy". On the hill roads boulders had been loosened, and there were numerous slips and surface cracks.

All but three of the brick chimneys in the village had to be demolished and re-built,



FIGURE 5. LAKE COLERIDGE HYDROELECTRIC POWER STATION.

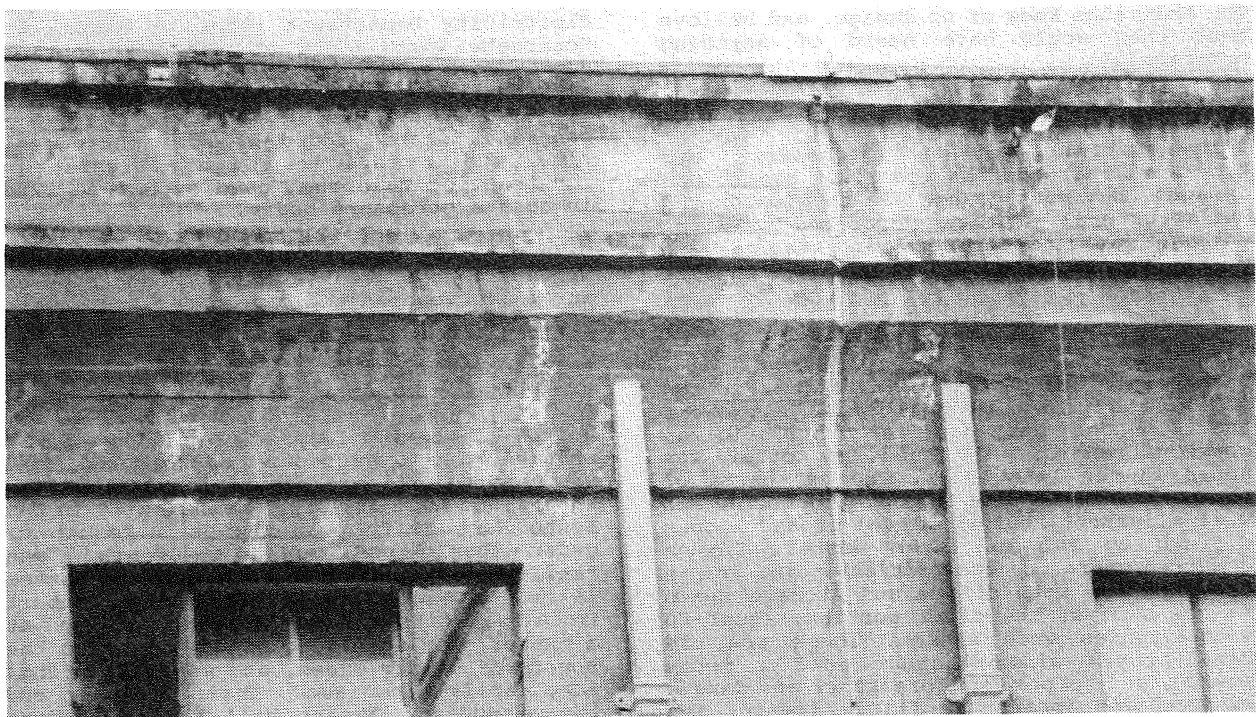


FIGURE 6. DETAIL OF THE JUNCTION BETWEEN THE OLD AND NEW PARTS OF THE POWER STATION.

but only one actually collapsed. Breakages of bottles and crockery were reported throughout the district.

Acheron River Bridge

Baird reported that that at Acheron River bridge a built up road cutting had slumped towards the river.

MINOR EFFECTS

Isolated examples of minor structural damage occurred in Greymouth, where a chimney and a chimney-pot were reported to have fallen, in Geraldine, where chimneys were cracked, and in Rangiora, where there was unspecified damage to a wireless aerial. A fallen chimney-pot was reported from Christchurch, and in Hokitika plaster fell from the wall of the public library.

Instances of displaced and broken crockery and other goods were reported from as far away as Fairlie, Waimate, and Dunedin, but even in Christchurch and Greymouth they were not sufficiently general to warrant extending the MM-VI isoseismal.

Two widely reported indications of intensity have become rare in present-day reports - the swinging of lights, and the misbehaviour of pendulum clocks. This affords a good example of the need for periodical revision of intensity scales if the degrees of intensity assigned in different earthquakes are to remain comparable over extended periods of time.

Large public clocks were stopped in Geraldine, Greymouth, Timaru, and Waimate, and "hundreds" of smaller ones in Christchurch according to the "Star-Sun". The escapement of the Post Office clock in Cathedral Square was damaged, allowing the minute hand to sweep around in two minutes, releasing the chiming mechanism at each passage. Swinging lights were observed through the whole of the felt area.

There was no panic, even in places near the epicentre, but alarm at sudden awakening was fairly general, and in both Christchurch and Dunedin hotel guests left their rooms.

ANIMAL REACTIONS

Many residents of the Lake Coleridge district remarked upon the quietness of birds during the period of the earthquakes. On the night before the main shock the stable-hand at Mount Algidus found it impossible to stable the horses, which remained greatly uneasy. Nausea was experienced by several people in Geraldine, some of whom claimed that this had preceded the earthquake.

EARTHQUAKE LIGHTS

The "Westport News" reported that at the time of the shock "flashes of electric discharge were seen along the hills towards Denniston", but according to the "Christchurch Press" the ship Gael

experienced a severe electrical storm between Cape Farewell and Karamea. This item of news was unrelated to the earthquake. It is therefore not possible to confirm an appearance of "earthquake lights".

FORESHOCKS AND AFTERSHOCKS

Two foreshocks were reported, but only the one of magnitude 4.3 at 12h 13m 12s.5 U.T. (Origin 46/90), 21 minutes before the main event, was instrumentally recorded. It was assigned an epicentre, based on only four stations, at 43°.44S, 171°.44 E, about 50 km to the southwest of it. The other, one minute before the main shock, was felt only at Lake Coleridge, with an intensity of MM-III.

Aftershocks were numerous, noisy, and persistent. The sounds were generally described as booms or explosive blasts, and were not reported from outside the epicentral region. Mr J. Mossop, Postmaster at Lake Coleridge, counted 63 aftershocks within five minutes of the main event, after which they became too numerous to report. His reports resume about two hours later, and record another 66 felt earthquakes. Only twelve of these could be independently confirmed, but there is little reason to doubt their reality, except in the case of the 8 and 6 shocks supposed to have been felt at Mount Oakden on October 26 and 27 respectively. The heaviest, with an intensity of MM-V, is said to have produced cracks up to 16 inches (40 cm) wide in the ground, and "to have been the only one felt at Lake Coleridge". The Power Station authorities have no record of a belated aftershock of this intensity, and Mr Robertson, the runholder at Mount Oakden at the time of my visit, had no knowledge of a second strong shock. The Andersons were certain that nothing was known of it at Mount Algidus, and suggested that a new account of the earlier shock could have been occasioned by the long-awaited arrival of a bricklayer in the district. Difficulty in obtaining one had been a major cause of local discontent.

Seven shocks within two hours of the main event were strong enough to be felt in Hokitika. These were confirmed instrumentally (Origins 46/92 - 99). The largest aftershock (Origin 46/115, Magnitude (ML) 5.8) occurred in the early evening of June 28, and was reported from most places that reported the main shock, the intensity being in general one degree less. Two other shocks (Origins 46/95, and 125) reached magnitude 5. In both cases the approximate limits of the felt area were set by Christchurch and Greymouth.

The activity continued with little intermission until late in August, with the exception of a very small shock on November 4 (Origin 46/199, Magnitude 2.8) it then ceased until January of the following year, when small shocks in the area previously active resumed, and continued throughout 1947 and with less frequency through 1948. In 1949 there was a shock of magnitude 4.5 on December 9 which probably belongs to the sequence (Origin 49/250) and brings it to an end.

In view of the sporadic character of the activity of the Central Seismic Region and the duration of the sequence, it seems legitimate to ask whether all the shocks in the period before 1949 December should be classed as aftershocks. Certainly the sequence is very long for an earthquake of magnitude 6.2, and perhaps the shocks after 1946 August could be regarded as an expression of the normal behaviour of the Region. After the shock on 1949 December 9, however, it remained completely quiescent until 1952 April 13. The first of several later quiescent periods began in 1954 October. After each of these periods the activity became concentrated in a different part of the Region. Not until 1973 did it return to the neighbourhood of Lake Coleridge. There seems to be some real sense in which the shocks before 1949 December were part of a single event. Whether they should be described as "aftershocks" may be a question of semantics.

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