

or lessened, this displaces the focus on the camera-screen only by half that distance, and an adjustment of lin. on the tube represents about 2in. of difference in the camera.

The eyepiece taking the place of the camera-screen is adjusted to the plane of the sensitive surface of the plate in the dark slide, and is easily brought to as great a degree of exactness as the dark slides themselves will register, and if needful it may also be made to compensate any displacement of the foci that may occur through using an imperfect telescopic eyepiece. In using the screen eyepiece the picture should be first arranged, and a proper balance of focus obtained; then, throwing back or aside the screen, the eyepiece may be applied to the production of focal sharpness, which may thus be made as perfect as lies within the capacity of the lenses concerned in its production.

Such, so far, have been my experiments and discoveries, and in bringing them and the instrument under the notice of the Society I do so with a view to their publication, so that others may have the opportunity of making improvements on what I have already effected, or of suggesting something entirely new in its place.

ART. LIV.—*The Determination of the Origin of the Earthquake of the 5th December, 1881, felt at Christchurch and other Places.*

By GEORGE HOGBEN, M.A.

[Read before the Philosophical Institute of Canterbury, 2nd October, 1890.]

Plate XLI.

I BEGAN to examine into the circumstances of this earthquake in connection with the general work of determining the origins of New Zealand earthquakes, and expected to find that the source of the disturbance was situated beneath the surface of the earth somewhere in the neighbourhood of Castle Hill, or (as Professor Hutton suggested to me in conversation) between Mount Torlesse and Mount Franklin. The evidence, however, gives a different result, and yet I believe is sufficient to show that the epicentrum is at or near the same spot as that of the 1st September, 1888.

The facts on which the present notes are based are related in the *Lyttelton Times* and *Press* of the following days. Very full accounts are given, but the number of data exact enough for our purpose is small.

The places at which the earthquake was felt are as follows:—

Place.	Time.	Apparent Direction.	Apparent Duration.	Effects. Remarks.
Christchurch	a.m. 7.37 or 7.38	N. to S. or N.E. to S.W.	10-35 secs.	Piece fell off cathedral tower. Chimneys, ceilings damaged, bells rung, panes broken, articles thrown off shelves, water in open vessels spilt; Avon stopped flowing for a moment, then flowed slightly more quickly. Not so much damage as 1868. Several clocks facing E. and W. stopped, but those facing N. and S. went on.
Lyttelton ..	7 h. 36 m. 43 s., N.Z.M.T.	N. and S...	..	"Sharp" (or "very severe"). S.s. "Wakatipu" heeled over on to wharf. No damage. Clock at time-ball tower stopped at time named. Town-clock bell struck several strokes at 7.38; several clocks stopped then.
Rangiora ..	7.33 ..	S.E. to N.W.	Nearly $\frac{1}{2}$ min.	No damage done. All pendulum clocks, including town-clock, stopped at 7.33. One of the sharpest since 1871.
Kaiapoi Waikuku .. Saltwater Creek	7.35 ..	..	..	No damage of consequence. Some artesian stopped flowing for a time.
Cust .. Oxford ..	.. About 7.45	E. to W. E. to W. ..	70-80 secs.	Unusually heavy. Chimneys moved $\frac{1}{2}$ in. to 2 in. A few, badly constructed, overthrown. Bottles off shelves. Nearly all clocks stopped.
Prebbleton	7.35 ..	E. to W. ..	..	"Sharp." School-bell at Lincoln rang. No damage.

Place.	Time.	Apparent Direction.	Apparent Duration.	Effects. Remarks.
Leeston ..	a.m. 7.35 ..	N.E. to S.W.	..	"Smart." Accompanied with slight rumbling. Some clocks stopped.
Sheffield ..	7.34 ..	W. to E. ..	..	Rather sharp. Preceding and succeeding tremors.
Kowai Pass (Springfield)	About 7.35	N.E. to S.W.	Upwards of $\frac{1}{2}$ min.	"Violent oscillation." Bottles off shelves. "More violent than twelve years ago."
Ashburton..	7.40 ..	..	..	The most severe since settlement of district.
Lyell ..	7.35 ..	E. to W. ..	5 secs.	
Wairau ..	About 7.30	N. to S. ..	20 secs.	
Westport ..	7.34 ..	..	..	Three distinct shocks; more than ordinary force.
Greymouth	7.33 or 7.30 (about)	W. to E., then N. to S.	20-30 secs.	"Heaviest ever experienced." Two sharp and distinct shocks. No damage.
Kumara ..	7.35 ..	From N.W., then S.W. to N.E.	..	Two shocks. Second shock was heaviest on the West Coast since 1868.
Hokitika ..	7.30 or 7.37	S. to N. ..	$\frac{1}{2}$ min. ..	Very strong and distinct shock.
Ahaura				
Wellington	7.30 ..	..	..	Slight.
Timaru	7.37 or 7.45			
Akaroa ..	7.30 ..	E. to W. ..	..	Very smart. No damage.
Dunedin ..	..	..	..	Seemed to be six shocks in immediate succession.
Hurunui ..	About 7.35	S.W. to N.E.	Nearly 2 min.	

Remarks on the Above.

Christchurch.—To the newspaper accounts I might add my own observation, taken at Christchurch and noted at the time. But as, unfortunately, I cannot at present find the note in question, I have refrained from making any use of the observation in my calculations. As far as my memory serves, however, the note states that the time (afterwards checked by a clock at Messrs. Coates and Co.'s) was 7.36 a.m.; the direction of the first shock, from between N.W. and N.; its duration,

fifteen to twenty seconds: the second shock, at right angles to the first, began before the first had died away, and so gave to most people the impression of a twisting motion; it was of undefined duration, but more marked in most of its effects than the first shock. This agrees remarkably with the result presently arrived at.

Rangiora.—The pendulum of the town clock vibrated in a plane W. by S. to E. by N. Other clocks, at right angles to this direction, also stopped. Mr. T. W. Rowe has been good enough to ascertain this fact for me.

The two movements, the normal and transverse, are clearly distinguished at Greymouth, Christchurch, Rangiora—in the last two places the stopping of the clocks gives a direction at right angles (or nearly so) to the direction said to have been noted. Most of the given directions can be explained only either on the hypothesis of error in observation, or on the hypothesis that it was the transverse motion whose direction was noted. The transverse motion seems to have been more marked everywhere; and, even were it not so, it is natural that people should mark its direction more carefully than the movements taking place in the first moments of surprise. The time 7.37 or 7.38 at Christchurch is on any hypothesis of the origin inconsistent with the best time given, 7h. 36min. 43sec. a.m., New Zealand mean time, at Lyttelton. Most of the times are approximate, being to the nearest five minutes only.

Determination of the Origin.

1. *By Direction of the Shock.*—By drawing straight lines on a map through the given places in the directions named, and at right angles thereto in case these directions may be those of the transverse vibrations, we find three possible circles to cut or touch a fair number of the lines drawn, within which the epicentrum is to be looked for: (1.) A circle, centre A (see Pl. XLI.), radius ten miles and a half, an epicentrum within which would agree roughly with Lyell, Sheffield, Greymouth, Hokitika, Rangiora, Waiau, and Kaiapoi (almost). (2.) A circle, centre B, radius thirty miles, agreeing with Hokitika, Sheffield, Rangiora, Christchurch, Lyell, Waiau, Greymouth. Note that this circle has to be made very large to include a fair number of the directions, and is not quite consistent with the probable correct assumption that east to west is the direction of the normal wave at Greymouth. (3.) A circle, centre C, radius seventeen miles and a half, agreeing with Christchurch, Lyell, Sheffield, Hokitika, Waiau, Rangiora, Oxford, Greymouth, Hurunui, &c.

The circle, centre B, answers to the facts which give at first sight the impression of an origin near Castle Hill; but it is worthy of remark that I did not, with any combination of

the time-observations employed, get an epicentrum situated within that circle.

2. *By Time-observations.*—Those used were—Rangiora, 7.33;* Greymouth, 7.33;* Westport, 7.34;* Sheffield, 7.34;* Lyttelton, 7.36 $\frac{3}{4}$;* Lyell, 7.35; Kumara, 7.35; Hokitika, 7.37; Christchurch, 7.37. The remaining times are either of doubtful value, or are inconsistent with any possible theory.

3. *Method of Straight Lines* (Milne, p. 200).—Four lines are available—those got, namely, from the times at the following pairs of places: (a) Rangiora–Greymouth, (b) Westport–Sheffield, (c) Lyell–Kumara, (d) Hokitika–Christchurch. The intersections of these lines give as possible positions of the epicentrum the six points marked with dots on the map. (d is one of the intersections of the last-named line, Hokitika–Christchurch.) All the points except (d) are within the circle C, and immediately to the north of Lake Sumner. The intersection of (a) and (b) gives D, within a mile of F (see below).

4. *Method of Circles* (Milne, p. 201).—I tried fourteen or fifteen combinations of the given data, and the positions obtained for the epicentrum are shown with small crosses on the map. Most of these lie in the north-east quadrant of the circle A. E is obtained from Lyttelton, Rangiora, Sheffield, Greymouth, and nearly agrees with Westport. It corresponds to a surface-velocity of six miles per minute, and a time at the centrum of 7.23 $\frac{3}{4}$ or 7.24 a.m. Its position is about 16 miles almost due north of the south-east end of Lake Sumner.

5. *Method of Co-ordinates* (Milne, p. 206).—The most satisfactory results are given by the first five of the times named in Method 2. The equations give an epicentrum F, 10 or 10 $\frac{1}{2}$ miles north of the middle of Lake Sumner, 172° 16' E. long., 42° 34' S. lat.; velocity, 7.18 miles per minute. The equations show themselves not exact enough to determine either the time at the centrum (they give 7.27 $\frac{1}{4}$) or the depth of the latter. By trial it is found, however, that a time at the origin 7.26 a.m., and some depth less than ten miles (perhaps less than five miles), will agree best with the position and velocity found.†

Intensity.—Whether we take F, E, or D, the velocity appears to have been very small—only 500ft. or 600ft. per

* Most reliable.

† The occurrences reported to have been witnessed at Lake Sarah (N.Z. Journal of Science, vol. i., p. 176; Trans. N.Z. Inst., vol. xv., p. 533) can very well be explained as secondary effects of the earthquake. The statements of damage to the buildings, as far as they are opposed to our conclusion, can hardly weigh against the remaining evidence. Indeed, the damage done to the south-east corner of the Castle Hill Hotel suggests the transverse vibration of a wave proceeding from the north-east—that is, from the epicentrum found.

second—and the earthquake, therefore, a very slight one, as measured by the intensity of earthquakes in other parts of the world.

The technical assumption has been made that the epicentrum is a point; the argument seems to show that it is not of large extent; with our data we cannot determine its size or shape. F, E, D, are all within a few miles of the epicentrum, as determined by Professor Hutton (*Trans. N.Z. Inst.*, vol. xxi.), of the earthquake of 1st September, 1888. It is noteworthy also that the geographical distribution of the shock, though not quite so great, is the same, as far as it goes, as the distribution of that earthquake. The fact that both the earthquakes that have injured the Christchurch Cathedral have proceeded from the same place may be worthy of practical consideration in any attempts that may be made to guard against possible damage in the future.

ART. LV.—*The Origin of the Earthquake of the 27th December, 1888, felt in Canterbury and Westland.*

By GEORGE HOBGEN, M.A.

[*Read before the Philosophical Institute of Canterbury, 6th November, 1890.*]

Plate XLIII.

THIS earthquake was felt generally throughout Canterbury and Westland, and, though it was of a slight nature, the shock or shocks were so distinct, and the observations (in the absence of instruments) appear to have been so accurately taken, that the epicentrum can be determined with great exactness.

The principal data are as follows: Greymouth, 9.32 p.m.; Waikari, 9.29 p.m.; South Malvern, 9.28 p.m.; Sheffield, 9.28 p.m.; Christchurch, 9.27 p.m.; Ashburton, 9.27 p.m.; Dunsandel, 9.26 p.m.; Akaroa, 9.26 p.m. (or 9.25½ p.m.).

Inquiry made into the circumstances of these observations at the time seemed to show that those at Akaroa and South Malvern were the most exact. For the former I am indebted to Mr. W. Walton, then headmaster of the Akaroa High School, and the two times given represent the limits within which the beginning of the shock took place. That at South Malvern was taken by myself. In each of these cases the second as well as the minute was taken, and the times were verified as soon as possible afterwards by New Zealand mean time. They are almost certainly correct within a quarter