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 Hogben, M.A.

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

Plate XLII.

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

of a minute. The times at Greymouth, Waikari, Sheffield, and Christchurch are also probably correct to half a minute—that is, to the nearest minute. Those at Ashburton and Dunsandel are more doubtful; but even the inclusion of these does not give results widely divergent from the others.

The directions noted are far less satisfactory, probably on account of the apparently twisting character of the movement, or, more strictly, the quick succession of the transverse movement upon the normal movement.

The methods employed in determining the epicentrum were the methods of straight lines, of circles, and of co-ordinates. The last, however, gives such definite results for the origin itself that it will be enough to state those alone, remarking only that the other methods do not disagree therewith, or show only such slight disagreements as can be explained without any straining of the evidence.

Taking Greymouth as the origin of co-ordinates, its meridian as the axis of x, and the axis of y eastwards, from the times at Greymouth, Waikari, South Malvern, Christchurch, Akaroa, we get the following equations (see Milne's "Earthquakes," p. 207) :—

$$\begin{aligned} 64x+150y+\ 9u-3w&=\ 6{,}649.\\ 138x+\ 76y+16u-4w&=\ 6{,}205.\\ 142x+148y+25u-5w&=10{,}517.\\ 184x+180y+36u-6w&=16{,}564. \end{aligned}$$

The solution of these gives us—

$x =$ 118 miles.
$y =$ 83 miles.
$u =$ 367, $\therefore v =$ 19·21 miles per hour (velocity of propagation).
$w =$ 5,605, $\therefore t =$ 7·636 minutes,

and time at the origin 9h. 24·364min. p.m.

$z =$ 24·2 miles (depth of origin).

O on the accompanying map (Pl. XLII.) marks the position of the epicentrum: taking this and the depth of the actual centrum to be correct, we find the distances from the centrum, and the time at the origin as found by reckoning back from the times observed at the several places, to be as follows :—

Greymouth	144 miles	9h. 24·5min.
Waikari	86 "	9h. 24·5min.
South Malvern and Sheffield ...	69 "	9h. 24·4min.
Ashburton	60 "	9h. 23·9min.
Dunsandel	54 "	9h. 23·2min.
Christchurch	51 "	9h. 24·34min.
Akaroa	35 "	9h. 24·2min.

The agreement (the time at the origin, of course, should theoretically be the same from whatever place it is determined) is remarkable. No other assumed depth gives by trial any results so close. For Akaroa, in the last table, 9.26 is taken as the time of the beginning of the shock; it was, however, probably nearer to 9.25½ than to 9.26. Taking it as 9h. 25·7min., the origin of the shock felt there should be nearly 8 miles nearer to Akaroa. A is the nearest point to Akaroa that the other data will allow. In the same way the Ashburton time may be made to agree with the rest by supposing an extension of the disturbed area above the origin in the direction of B. I have therefore marked A O B as a possible boundary of the epicentric area. I have little doubt about the portion O A;* but the other portion, O B, is far within the limits of error, and is not more, therefore, than a speculation.

Professor Hutton, in a letter to the *Press*, gave the epicentrum as H. (See Pl. XLII.) He used, however, only part of the above data, and, finding that I was engaged on the question, did not pursue the matter further, but courteously gave way to me.

To sum up: The earthquake had its origin beneath the sea at a point (O) 45 miles south-by-east from Christchurch, nearly opposite Akaroa Heads and the mouth of the Rakaia; in longitude 172° 51′ E., latitude 44° 10′ S.; at a depth of about 24 miles. The shock took place at the origin at 9.24⅓ p.m., and was propagated with a velocity of 19⅕ miles per minute, or 1,690ft. per second.

The chief interest connected with the determination of this earthquake-origin is, that I think it will be found that most of the small earthquake-shocks felt from time to time in Christchurch and its neighbourhood proceed from the same region. For instance, there is very little doubt that a series of earthquakes on the 5th and 6th of June, 1869—much discussed in the newspapers at the time—had their origin at nearly, if not quite, the same spot.

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* Even the later time, 9.26 p.m. at Akaroa, requires us to suppose some extension of the epicentric area towards A. By assuming further that the portion of the earth's crust where the disturbance originated (or the focal cavity) was nearer the earth's surface in the direction of A than at O, we may make the agreement of the data from the six best places perfect. Without complete seismographic apparatus, however, such an assumption can be no more than a mere conjecture.