

XXIV.—*On the more notable Scottish Earthquakes which have occurred during the present century.* By RALPH RICHARDSON, F.R.S.E., Vice-President. [*With Map.*]

(Read 19th March 1891.)

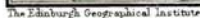
INTRODUCTION.

SCOTLAND has by no means an immunity from earthquakes. On the contrary, as the following paper will show, several earthquakes of considerable energy and affecting a wide area, have periodically occurred. In addition to these, there have been many hundreds of shocks, recorded and unrecorded, in various parts of the country. Mr Robert Mallet in his fourth Report to the British Association on earthquake phenomena, published in 1859, tabulates (p. 5) 234 "Earthquakes of the British Islands and Northern Isles," and points out that, of these, 56 occurred in Winter, 42 in Spring, 52 in Summer, and 67 in Autumn. The relative number for the four seasons was, Winter 1·03, Spring 0·76, Summer 0·96, Autumn 1·24; and during the two months of Perrey's "critical epochs," the number was as follows:—Winter solstice 1·28, Spring equinox 0·96, Summer solstice 0·53, Autumnal equinox 1·13.

Then, as to the horizontal direction of British earthquakes, Mallet remarks that Perrey computed a mean horizontal direction of S. 39° 5' W. to N. 39° 5' E., which is about the line of fracture of Loch Ness and the Great Glen.

Our late President, Mr Milne Home, discussed the earthquake phenomena of Scotland so long ago as 1842, in the "Edinburgh Philosophical Journal" (vols. xxxi.-xxxvi.), and the table of British earthquakes which he gives is interesting as exhibiting the time of year when the shocks occurred. It is as follows:—

	Scotland.	England.	Total for Great Britain.
January	14	11	74. Winter months.
February	14	13	
March	12	10	
April	9	10	44. Spring months.
May	8	4	
June	4	9	
July	5	5	58. Summer months.
August	12	9	
September	12	15	
October	14	11	79. Autumn months.
November	20	12	
December	15	7	
	139	116	



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During the present century, the most remarkable earthquakes which occurred in Scotland were those of the years 1816 and 1839. I shall therefore give some details of these, but I shall also, by way of comparison, refer to the well-observed earthquakes of 1801, 1880, 1889, and 1890, so that we may have before us at one time all the more notable Scottish earthquakes of the century. To facilitate comparison, I have constructed the accompanying map, which shows us at a glance the area affected by each of these earthquakes, as well as the great lines of fault and fracture in Scotland.

1st. *The Earthquake of 7th September 1801.*

Mr Thomas Lauder Dick¹ refers to this earthquake in the *Scots Magazine* of November 1816, in the course of an article on the important earthquakes of that year. In 1800 a slight shock had been felt at Inverness, which, as we shall find, is a locality noted for earthquakes. On 7th September 1801, a smart shock was experienced in the New Town, but not at all in the Old Town of Edinburgh, and in Leith and vicinity. A block of houses sank so considerably that the inhabitants had to leave it, whilst in Mid-Lothian a barn fell, crushing two women to death. Mr Lauder Dick considers that this earthquake had its centre in that well known seismic focus, Comrie, and says it was felt at Lochearnhead, Killin, Tyndrum, and Glenfinlas, extending southwards to Glasgow. It was also experienced at Perth, Callander, and on both sides of the Firth of Forth, at Grange-mouth, Torryburn, Culross, Dunfermline, &c. The *Scots Magazine* of September 1801, says the barometer was high and had been rising for some time before. It adds that so extensive a shock had not been experienced in Scotland since the great earthquake at Lisbon on 1st November 1755, which was felt over a wide area in Europe, and which caused the waters of Lochs Lomond, Tay, and Ness, as well as of lakes and ponds throughout England, to rise and fall.

Turning to the *Edinburgh Magazine* for September 1801, we obtain greater details regarding the earthquake of 7th September. It continued two or three seconds at Edinburgh, and was preceded by a rumbling noise. Beds, tables, and chairs shook violently. The shock occurred at 6 A.M., and the morning was gloomy, warm, and calm. A previous slighter shock was noticed at 4 A.M. The earthquake was felt at the following additional localities,—viz., Paisley, Renfrew, Hamilton, Ayr, Stirling, Alloa, Linlithgow, and Amulree, Brig o' Turk, and Abernethy in Perthshire. At Comrie, two shocks occurred on 6th September (Sunday),

¹ Afterwards that well-known writer, Sir Thomas Dick Lauder, Bart.

and alarmed a congregation in church. Next day a shock occurred at break of day, followed about 6 A.M. by one which is described by a local observer as "very great and alarming beyond expression. The earth, the great mountains around this village (Comrie), and the houses trembled like a balance for about the space of a minute. Slates fell from some houses, and many loose bodies tumbled down with great precipitation." This observer remarks that earthquakes have visited Comrie with more or less violence since August 1789, and generally happen at full moon or the change. The Aurora Borealis was very vivid for several nights before the earthquake of 7th September 1801.

From a table in the *Edinburgh Magazine* I observe that on 7th September 1801 the barometer at Edinburgh registered 29·7, whilst the thermometer was 48° before sunrise and 58° at noon. New moon occurred on 8th September, the day following the earthquake.

2nd. The Earthquake of 13th August, 1816.

Whilst Comrie was considered the centre of the earthquake of 1801, Inverness and its vicinity were believed to be the focus of that of 1816. According to the *Scots Magazine* for August 1816, the earthquake which occurred on 13th August of that year extended entirely across Scotland in a direction from W.N.W. to E.S.E. It was felt on the western coast of Ross-shire at Gareloch and Applecross and it strongly affected Coul, 18 miles to the west of Inverness. Inverness and its environs were rudely shaken a little before 11 p.m. Many persons (writes a local observer) fled from Inverness to the fields, and remained there for the greater part of the night. Chimney-tops were thrown down or damaged. A hotel was rent from top to bottom, whilst a spire was so seriously damaged that part required to be taken down. The day on which the earthquake occurred had been in Inverness beautiful and serene, and the weather remained unchanged. The barometer did not fall. I observe that at Edinburgh on 13th August 1816 the barometer was 30·05. New moon occurred on 23rd August.

From the *Inverness Journal* of the period we learn that the concussion on 13th August lasted about 20 seconds, and in many houses the bells rang for nearly a minute. The spire attached to the jail was found to be, at a distance of several feet from the top, completely rent and twisted several inches round in a direction from E. towards N.W. The earthquake was felt at Dingwall, Forres, and Pitmain, but it was more violent towards the north and west than towards the south and east.

At Montrose, however, the earthquake shortly before 11 p.m. seriously alarmed many families, and awoke them from sleep.

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Chairs and tables were put in motion, and next morning many doors were found difficult to open. One gentleman observed his bookcase move from the wall and fall back again upon it. The shock was felt in the vicinity of Montrose as far as Johnshaven. Two excisemen there were on the watch for smugglers, and were lying on the ground when the shock occurred, whereupon one of them leaped up and called to his companion: "There they are, for I feel the ground shaking under their horses' feet."

At Aberdeen also, about 11 p.m. the shock was distinctly felt for about 6 seconds. The undulation seemed to come from S.S.E., moved the heaviest articles of furniture, and set bells ringing. At Relugas, Morayshire, the seismic sound resembled that "of a great many pieces of heavy artillery driven furiously over a vaulted pavement," whilst everything was "heaved up and down." The barometer there was unaffected, and the thermometer marked 54°. At Logie, Lochindorb, Forres, Auldearn, Moy, and Grange the same alarming phenomena were observed; whilst at Dornoch, north of Inverness, the arches of the mound across the little ferry fell on account of the earthquake. At Peterhead, Fraserburgh, Dunkeld, and Perth the earthquake was also experienced for several seconds.

As already stated, Sir Thomas Dick Lauder, a well-known geological authority, described this and other Scottish earthquakes in the *Scots Magazine* for November 1816. He considers that the earthquake of 13th August 1816, "as it appears to have been infinitely more violent, so its influence seems to have been of wider extent than that of any of those which have hitherto agitated Great Britain." Whilst it was slightly felt at Glasgow, Coldstream, and Edinburgh, its range of active exertion lay between the Tay and the Pentland Firth. The total area affected must have been about 240 miles from north to south and about 160 miles from east to west. Strange to say, it did not agitate the waters of Loch Ness (as the Lisbon earthquake did), although the seismic centre was so near. The great bell of Inverness was distinctly heard to toll twice during the earthquake. Dick Lauder makes contradictory statements as to whether alluvial or rocky foundations were most affected by the earthquake, the truth apparently lying in his general observation "that every geognostic denomination of country seems to have submitted to the influence of the agitating power."

Nor was the Inverness district free from earthquakes after the great one of 1816, for, up to August 1817, five shocks were felt in Inverness, although (the *Scots Magazine* of September 1817 remarks) "the concussion was more violent in the districts of Urquhart, Aird, &c., to the westward of Inverness."

3rd. The Earthquake of 23rd October 1839.

Mr Milne Home gives full particulars of this extensive earthquake in the "Edinburgh New Philosophical Journal" (vols. xxxii. *et seq.*) published in 1842-44. The "apparent focus of violence," according to him, was Comrie, a place where earthquakes have occurred so frequently that, for the two years following 3rd October 1839, 247 shocks are recorded in it,—171 during the six winter months from October to March inclusive, and 76 during the six summer months. Taking Comrie as a centre, and remarking that the earthquake of 23rd October 1839 was "the severest, unquestionably, of any which, within the memory of the oldest inhabitants, had been felt there," Mr Milne Home proceeds to note the localities affected and give the reports of observers. He first gives the accounts from Strathearn, the valley in which Comrie is situated, with reports from Lawers, Monzie, Crieff, and other places. The shock was felt about quarter-past ten at night without any previous warning. At Lawers "a loud and terrific explosion" was heard. A "tremulous motion passing along to the east was imparted to every object." The barometer had fallen an inch since 12 o'clock noon, and now stood at 29.8. Half-an-hour afterwards another loud explosion occurred, with the tremulous motion repeated, but the barometer was unaffected. The thermometer stood the whole night at 52°. During the night about 20 explosions occurred without any tremulous motion. Rain had fallen in the district incessantly for two whole days and nights, and Mr Milne Home remarks that especially during August, September, and October 1839, an unusual quantity of rain fell. The inhabitants of Comrie associate very wet weather with earthquake shocks.

Westwards from Comrie, this earthquake of 1839 was felt at Dunira, Ardvairlich, Glenbuckie, Callander, Luss and Cameron House on Loch Lomond, 3 miles S.-W. of Glasgow; and Finnart on Loch Long. To the north-west of Comrie it was felt at Clenary, 4 miles from Inverary, Dunolly, near Oban, Ardgour, in Inverness-shire, and at Appin. To the north of Comrie it was felt at Dull in Aberfeldy, Kingussie on Speyside, Inverness, Fort Augustus, Glen Urquhart, Strathglass, Beaully, Dingwall, and Forres. To the north-east of Comrie the earthquake was felt at Fraserburgh, 110 miles from Comrie; Strichen near Fraserburgh, Banchory, Aberdeenshire; Finzean, Aberdeen, Blairgowrie, Spittal of Glenshee, and Kirkmichael in Strathardle. Then to the east of Comrie, it was felt at Shanwell near Kinross, Kinross town, Perth, and St Andrews. To the south-east of Comrie it was felt at Balgone near North Berwick, Musselburgh,

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Prestonpans, Newbyth, Trinity, Edinburgh, Dunning, Muckhart in Ochils, Dollar, Tillicoultry, Alva, and Alloa. To the south of Comrie it was felt at Airth and Throsk near Stirling, Stirling, Thornhill, Blairdrummond, Bucklyvie, Selkirk, Kelso, Coldstream, Closeburn, Dumfriesshire; and Netherby Hall, 10 miles north of Carlisle.

From this recital of localities, it is evident that the area affected by this earthquake was most extensive. "The shock," says Mr Milne Home, "was felt throughout two-thirds of Scotland." Again, the rapidity of the passage of the earthquake is most extraordinary, all this vast region being apparently struck simultaneously, the blow, however, being felt most severely at Comrie. One observer at Comrie reported "I felt the shock strike the ground perpendicularly under my feet three times, like the stroke of a ponderous hammer; and as far as I can guess, lifted the ground six or eight inches." "In a great number of the reports, it is remarked that the undulations were most striking in carse or alluvial grounds, though the accompanying *noise* was not so great there as on rocky ground." Comrie, the centre of the earthquake, adjoins an important line of fault stretching from the Kincardine coast in a S.W. direction past Comrie to Loch Lomond.

Miss Milne Home has kindly shown me some correspondence¹ which, in March 1840, passed between her father, Dr Daubeney (the author of the well-known work on "Volcanoes") and Charles Darwin, regarding the earthquake phenomena of Scotland. In the course of that correspondence Darwin makes the following suggestion:—"On the hypothesis of the crust of the earth resting on fluid matter, would the influence of the moon (as indexed by the tides) affect the periods of the shocks, when the force which causes them is just balanced by the resistance of the solid crust?"

In this correspondence, Mr Milne Home describes certain curious phenomena observed not long after the great earthquake of 1839. He says that on 16th November 1839 "jets of smoke or steam were observed to issue from the side of a hill in Glenalmond, 8 miles north-east from the focus of the Comrie shocks, and stones were by these jets raised out of their beds." Again, on 15th January 1840, about 200 yards from the place where the jets of smoke or steam appeared, a flame was seen. On making enquiry, Mr Milne Home learnt that "such a flame has been seen occasionally for the last twenty or thirty years arising from the same spot." . . . "It shows itself chiefly in the winter time. Its colour is blue or purple. The place from which it issues is

¹ Given in full in her interesting *Life of our deceased President*, published by Mr Douglas, Edinburgh, 1891.

rocky and precipitous." Mr Milne Home consulted both Darwin and Daubeny as to the probable origin and nature of this flame. Darwin's reply has not been preserved. Daubeny thought it would "turn out to be a pseudo-volcanic phenomenon," and not necessarily connected with earthquakes. "Why," he asks, "should earthquakes be necessarily connected with volcanoes? Is it not more probable that those, for example, that are so frequent in the county of Sussex should be connected with some local cause of that kind, such, for example, as in the neighbouring county of Dorset has produced the landslip near Lyme accompanied, it is said, with shocks of the same description. . . . I assume, of course throughout, that the gas will turn out to be some form of carburetted hydrogen which, having become kindled by accident, goes on burning till extinguished. Should it turn out to be phosphuretted hydrogen, it would indeed be an addition to our knowledge."

4th. The Earthquake of 28th November 1880.

This earthquake is described by Mr Charles A. Stevenson in the *Proceedings of the Royal Society of Edinburgh* for 21st March 1881 (Vol. xi., p. 176), and seemed to have its centre near Phladda Lighthouse, to the east of Colonsay. Like the earthquake of 1839, it occurred after a wet period, the barometer ranging between 29 and 30. Like the 1839 earthquake also, its source or centre, Phladda, lay near a great fracture, namely, one which runs along the Great Glen in a south-westerly direction from Inverness. It was also a winter earthquake.

Mr Stevenson states that "the seismic area was about 19,000 square geographical miles, the shock having been felt as far north as the Butt of Lewis, as far south as Armagh in Ireland, as far east as Blair Atholl, and as far west as Barrahead, though how much farther it was propagated into the Atlantic it is impossible to say." The area influenced by this earthquake may be roughly said to be bounded by the towns of Inverness, Blair Athole, Callander, Motherwell, Ayr, Belfast, Armagh, Omagh, and Letterkenny; the circle being completed by the Outer Hebrides, as far north as the Butt of Lewis.

The earthquake was felt throughout this immense area almost simultaneously everywhere. For example, it was felt at Belfast in Ireland and at Ushenish, which is in the island of South Uist, at precisely the same moment—viz., 5.53 P.M., although these two places are 200 miles apart. Phladda (the supposed seismic centre) is about equi-distant from these two places.

Again, this earthquake, like that of 1839, raises the interesting point whether buildings erected on solid rock feel earthquake shocks more acutely than those built on other material. Mr

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Stevenson says that "the stations (mostly lighthouses) where the noise was heard were for the most part situated on hard, dense rocks, with little or no soil near them." Dr Johnston-Lavis of Naples, from his careful examination of the result of the disastrous Ischia earthquake of 1883,¹ came to the conclusion that houses built on rock suffer much more than those built on sand or tufa. In our Edinburgh earthquake of 1889, however, the shock was not felt by the soldiers living in the Castle, which is built on solid rock.

Once more, this earthquake of 1880 seems to corroborate Mr Milne Holme's view (Vol. xxi. p. 283²) that earthquakes are most frequently felt in localities where the more ancient rocks occur: for Mr Stevenson states "that of twenty-two lighthouse observers between Cape Wrath and the Mull of Galloway, who were situated on the older formations (Laurentian, Cambrian, and Metamorphosed Lower Silurian), eleven felt the shock; whilst of thirteen observers on newer rocks, it made itself known only to two of them." This earthquake therefore, in his opinion, was more generally felt on the older rocks of Scotland.

5th. *The Earthquake of 18th January 1889.*

Full details regarding this earthquake will be found in the paper which I read before the Edinburgh Geological Society on 21st February 1889, and which was published in the *Scottish Geographical Magazine* for March 1889, with an excellent map by Messrs Bartholomew, illustrating the times and apparent directions of the shocks. There were two shocks, but the second, shortly before 7 A.M., was the principal one. This shock was experienced throughout an area extending as far north as Burntisland, as far east as Dalkeith, as far south as Peebles, and as far west as Linlithgow. The city of Edinburgh felt it in numerous localities, but, as in the earthquake which occurred in 1801, the Old Town and the Castle do not seem to have been affected. Both during the earthquakes of 1801 and 1889, in this district, the barometer and thermometer were high. The earthquake of 1889 was a winter one, but did not occur after wet weather. The meteorological conditions, however, which produce accumulations of gas in mines, were present both during this earthquake and one which occurred throughout a great part of Scotland in 1888; and the disastrous colliery explosion occurred at Hyde, Cheshire, about two hours after the Edinburgh earthquake of 1889. Eclipses of the moon preceded the earthquakes of 1888 and 1889. Full moon occurred on

¹ Monograph of the Earthquakes of Ischia, especially those of 1881 and 1883, published at London and Naples, 1885. This masterly work is finely illustrated by photographs, &c.

² *Op. cit. supra.*

17th January 1889, and the earthquake was next day. Full moon occurred on 22nd October 1839, and the earthquake was also next day. Full moon cannot, however, be connected with the earthquakes of 1888 or 1890.

6th. The Earthquake of 15th November 1890.

My information regarding this earthquake is obtained from articles and letters which appeared in the *Scotsman* and other newspapers immediately after its occurrence. This earthquake¹ had a wide area, extending as far north as Dunbeath on the Caithness coast, as far east as Fraserburgh and Aberdeen, as far south as Huntingtower, near Perth, and as far west as Drumnadrochit and Strathglass. This area, wide as it is, is mostly included in the much more extensive area of the earthquake of 23rd October 1839, to which I have already drawn attention. The time of the first shock, on 15th November 1890, appears to have been a little before 6 P.M., and there was a second shock at 6.20 P.M. A clock was stopped at Inverness at 5.50 P.M., and the shock was distinctly felt at Huntingtower, near Perth, 80 miles distant, at 5.51. Like the other earthquakes noticed, this was a winter one, but it did not follow much rain. The barometer at Drumnadrochit was 30.1 and rising. Observers there thought the wave proceeded in a direction between E. and S.E. However, at Inverness an observer thought it passed S.W., and, as usual, observers differ widely in this matter. Spring tide, new moon, and a high barometer² all occurred at Inverness during or shortly preceding this earthquake, which was on Saturday, 15th November 1890, and was generally admitted to be "the greatest that had occurred in the district for many years." Next day (Sunday) a distinct shock was felt at Drumnadrochit at 8.29 P.M., and again the movement seemed to be in an easterly direction. The same morning (Sunday, 16th November), at half-past three o'clock, a sharp shock was experienced at Inverness. "The shock," said next day's *Scotsman*, "was of such severity as to waken almost the soundest sleeper, and for a time there was considerable excitement and alarm. In an instant, almost every house was lit up, and in several cases the people rushed to the street, under the belief that their houses would topple over. This shock is the eighth which has been distinctly felt along the valley of the Ness since

¹ An elaborate account of the Inverness earthquakes of 15th November to 14th December 1890, by Mr Charles Davison, appears, with a map, in the *Quarterly Journal*, Geological Society of London, vol. xlvii. p. 618 (November 1891). His map does not exhibit the full seismic area.

² Prof. Milne of Japan, in his able treatise on earthquakes in the "International Scientific Series" (1886) discusses these seismic influences.

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the 15th November, and in severity was only equalled by the first shock on the evening of that day." These frequent shocks about this period in the Ness valley do not seem to have been felt beyond it, and in this respect differ greatly from the shock on the evening of Saturday, 15th November, a little before six o'clock, which affected the wide area already noticed. With reference to a former remark as to the greater frequency of earthquakes on the older than the newer rocks, their occurrence so often in 1890 in the Ness valley is remarkable, as from Loch Ness to the sea the rocks of the Ness valley consist of Post-tertiary deposits. Dingwall also, where a "very severe shock of earthquake was felt a little before six o'clock" on the evening of Saturday, 15th November, is situated on deposits of Post-tertiary age. Inverness and Dingwall were affected by the four earthquakes of 1816, 1839, 1880, and 1890.

CONCLUSION.

In order to gather together, for comparison, some of the leading details regarding these the more notable Scottish earthquakes of the present century, I have prepared the following tables which, with the accompanying map, will give information never yet published in one paper.

A. Comparative Details of each Earthquake.

Earthquake.	Hour.	Approximate Area affected.		Supposed Centre.	Barometer at Centre.	Thermometer at Centre.	Phase of Moon.	Supposed Direction of Earthwave.
		Length. Miles.	Breadth. Miles.					
7th Sept. 1801,	6 A.M.	90	70	Comrie.	29.7 ¹	48° ¹	Day before New Moon.	From S.W.
13th Aug. 1816,	11 P.M.	200	142	Inverness.	29.8 ²	64° ²	Approaching last Quarter.	From W.N.W.
23rd Oct. 1839,	10 P.M.	217	188	Comrie.	29.8	52°	Day after Full Moon.	From W.
28th Nov. 1880,	6 P.M.	280	230	Phladda.	29.9	50°	Approaching New Moon.	From W.S.W.
18th Jan. 1889,	7 A.M.	35	35	Edinburgh.	29.9	53°	Day after Full Moon.	Uncertain.
15th Nov. 1890,	6 P.M.	130	130	Inverness.	29.9	51°	3 days after New Moon.	Uncertain.

¹ No records then kept at Comrie. The above readings are those taken in the vicinity of Edinburgh, where the earthquake was felt.

² No records then kept at Inverness. The above readings are those taken at Gordon Castle, Elginshire, where the earthquake was felt.

B. Alphabetical List of Localities affected by more than one notable Earthquake.

Locality.	Earthquakes of					
	1801	1816	1839	1880	1889	1890
Aberdeen,		x	x			x
Alloa,	x		x			
Amulree, Perthshire,	x		x			
Ayr,	x			x		
Callander,	x		x	x		
Coldstream,		x	x			
Comrie,	x†		x†			
Dingwall,		x	x	x		x
Dunkeld,	x	x				
Edinburgh,	x	x	x		x†	
Forres,		x	x			x
Fraserburgh,		x	x			
Glasgow,	x	x				
Inverary,			x	x		
Inverness,		x†	x	x		x†
Linlithgow,	x				x	
Nairn,			x			x
Perth,	x	x	x			
Stirling,	x		x			

† Supposed centre of the Earthquake.