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SECOND REPORT

ON

EARTHQUAKES IN JAMAICA.

(1881 DECEMBER 26th TO 1886 JUNE 3RD INCLUSIVE.)

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Colonial Secretary's Office, 7th March 1887.

THE OFFICER ADMINISTERING THE GOVERNMENT directs the publication, for general information, of Mr. Maxwell Hall's Second Report on Earthquakes in Jamaica.

By Command, E. N. WALKER, Colonial Secretary.

Second Report on Earthquakes in Jamaica.

The present Report is a continuation of the first Report published as No. 4 of the Weather Series in which details of ten shocks which were felt in Kingston during 1880 and 1881 were given, and of certain meteorological changes which seemed to accompany the shocks in an irregular manner, necessitating further observation before a study could be made of the connection between effects so widely dissimilar.

The following are the meteorological changes alluded to in the first Report:—

(1) The barometer, corrected for diurnal variation, rises 0.002 or 0.003 in. eight hours or so before a shock, falls about the time of the shock, and then rises again, having taken about a day and a half to go through these small variations.

(2) The wind, or rather the south-easterly sea breeze, is generally checked about the time of a shock; and if 100 miles of wind pass over Kingston both the day before and the day after the shock, only 76 miles pass during the day on which the shock occurs.

(3) The minimum, mean, and maximum temperatures of the air are not perceptibly affected by a shock; and consequently the weather is felt to become close and oppressive before or about the time of a shock in consequence of the stopping of the sea breeze, and not of any rise in temperature.

(4) After a shock has occurred, clouds increase in extent; if 41 and 42 are the percentages of cloud the day before and the day of the shock, then 47 is the percentage the day after. These earthquake clouds are thin horizontal sheets of *stratus*.

(5) Although the sky becomes more cloudy, little or no rain falls. The following are the totals for the ten days expressed in decimals of an inch:—before the shocks 0.10; on which the shocks occurred 0.32; after the shocks 0.05.

We have now to consider Earthquakes Nos. 11 to 26 inclusive which have been felt in Kingston since the first Report was written, and we shall tabulate the details as before.

No.	DATE.	Local mean time.	Intensity of shock.	DURATION. First shock.	Interval.	Second shock.	Total.
		hr. m.		Sec.	Sec.	Sec.	Sec.
11	1881, December 26 ...	11 48 p.m.	Moderate	.	.	.	1
12	1882, February 3 ...	2 0 a.m.	Light	.	.	.	2
13	" March 15 ...	9 15 p.m.	"	.	.	.	1
14	" December 27 ...	1 20 "	"	.	.	.	1
15	1883, April 8 ...	11 5 a.m.	"	.	.	.	1
16	" July 26 ...	early a.m.	"	.	.	.	1
17	1884, January 14 ...	1 15 p.m.	Strong	3	2	5	10
18	1885, February 28 ...	1 30 a.m.	Moderate	1	3	1	5
19	" August 30 ...	7 15 p.m.	Strong	5	5	23	33
20	1866, January 1 ...	9 30 "	Moderate	.	.	.	1
21	" February 20 ...	6 50 "	Light	.	.	.	1
22	" April 18 ...	4 48 a.m.	Moderate	.	.	.	1
23	" May 1 ...	7 7 "	Light	.	.	.	1
24	" " 12 ...	1 10 p.m.	"	.	.	.	1
25	" " 14 ...	11 42 a.m.	"	.	.	.	3
26	" June 3 ...	7 7 p.m.	Strong	5	1	18	24

For notes and comments on all these shocks we must refer our readers to the Jamaica Weather Reports which have been published each month since June, 1881.

Barometer: corrected and reduced, &c.

No.	24 hrs. before.	16 hours before.	8 hours before	At time of shock.	8 hours after.	16 hours after.	24 hours after.
	In.	In.	In.	In.	In.	In.	In.
11	30.015	30.041	30.028	30.021	30.018	30.018	30.055
12	30.081	30.101	30.094	30.084	30.075	30.018	30.015
13	30.111	30.105	30.085	30.056	30.054	30.026	30.054
14	30.056	30.041	30.019	29.995	30.013	29.994	29.973
15	30.014	30.050	30.047	30.020	30.042	30.064	30.015
16	30.051	30.022	30.046	30.029	30.007	30.035	30.008
17	30.061	30.047	30.043	80.016	30.024	30.063	30.056
18	30.014	30.051	30.038	30.063	30.062	30.046	30.068
19	29.954	29.960	29.994	30.013	30.015	30.014	30.000
20	29.996	29.993	29.989	29.980	29.966	29.949	29.957
21	30.021	30.053	30.056	30.018	30.063	30.052	30.030
22	29.809	29.817	29.826	29.835	29.814	29.850	29.885
23	29.990	29.962	29.964	29.970	29.955	29.959	29.962
24	29.996	30.000	30.024	30.013	30.047	30.045	30.033
25	30.013	30.047	30.045	30.033	30.043	30.053	30.041
26	29.988	29.967	29.985	29.963	29.951	29.949	29.929
Mean	**30.013**	**30.016**	**30.018**	**30.009**	**30.013**	**30.010**	**30.005**

These variations are larger than those in the first Report, and the fall at the time of shock is much more strongly marked.

In accordance with what follows, the method of registration hitherto employed is too general, and improvement will be made for the future.

No.	Miles of Wind.			Clouds and Rain.					
	Day before.	Day of shock.	Day after.	Day before.		Day of shock.		Day after.	
				Cloud.	Rain.	Cloud.	Rain.	Cloud.	Rain.
				o/o	in.	o/o	in.	o/o	in.
11	100	88	48	23	0.00	37	0.00	27	0.00
12	94	130	138	7	0.00	50	0.00	23	0.00
13	41	29	50	3	0.00	33	0.00	27	0.00
14	40	82	82	60	0 00	17	0.00	100	0.00
15	196	153	115	7	0.00	50	0.00	27	0.00
16	119	176	108	60	0.50	47	0.00	47	0.00
17	66	151	130	7	0.00	10	0.00	43	0.00
18	70	20	57	13	0.00	27	0 00	40	0.00
19	75	65	64	20	0.00	70	0.35	0	0.00
20	60	25	56	3	0.00	7	0.00	23	0.00
21	110	62 ?	63 ?	3	0.00	57	0.02	23	0.00
22	70	56	90	67	0.00	47	0.00	3	0.00
23	77	62 ?	62 ?	37	0.00	13	0.00	97	0.00
24	20	47	58	80	0.03	37	0.05	10	0 00
25	58	54	...	10	0.00	0	0.00	7	0.00
26	85	52	118	33	0.00	27	0.00	93	0.00
Mean	80	78	82	27	...	33	...	37	...

The decrease of the wind on the day of shock is not as strongly marked here as in the first Report: but the principle remains. Take for instance No. 17; there was the usual lull before the shock occurred, although the wind was high before and after. As in the case of the barometer, the method of registration will be improved.

No.	Temperatures of the Air.								
	Day before.			Day of shock.			Day after.		
	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.
11	65°.9	75°.2	88°.0	72°.[illegible]	74°.7	86°.1	66°.4	75°.6	83°.9
12	64.9	72.3	83 8	64.7	75.9	84.4	71 0	77.9	84.3
13	67.1	74.2	82.8	66.6	74.4	85.1	67.9	76 4	85 7
14	72.8	76.5	86.7	69.5	74.5	86.5	68 3	76.1	86.5
15	70.1	79.6	88.8	71 5	77.8	87.6	70.5	76.9	86.3
16	75.0	80.7	88.6	73 8	82.0	88.5	73.7	82.9	90.0
17	65.9	74.0	85.1	66.7	74.2	84.5	66 7	75.3	85.4
18	66.5	75.4	84.1	66.5	73.1	83 0	64 3	73.4	84.1
19	72.5	81.6	88.1	74.0	78.2	90.1	71 6	81.1	91.2
20	64.1	74.1	84 5	66 3	74.8	86.1	65.3	74.9	86.4
21	70.4	77.8	90.5	70.3	73.8	85 0	67.2	73.5	84.2
22	67.1	76.3	84.6	69.6	75.6	87.3	66.5	77.1	85.6
23	72.3	81.1	91 4	71.3	81.7	92.6	72.3	80.0	89.7
24	73.5	79.2	88.3	73 6	81.7	91.8	72.9	79.7	88.6
25	72.9	79.7	88.6	71.9	78.8	86.6	67.6	78.3	87.8
26	73.5	83 1	93.8	74.4	83.6	93.6	75.3	79.9	91.8
Mean	69.7	77.6	87.4	70.2	77.8	87.4	69.2	77.4	87.0

The slight diminution of temperature on the day after the shock is no doubt due to the increased amount of cloud as shown above

Let us now combine the former results with these, and adopt the combination as applying to an average earthquake shock.

			In.
(1) **Barometer**—	24 hours before shock	...	30.009
	16 hours before shock	...	.013
	8 hours before shock	...	.015
	At time of shock	...	.008
	8 hours after shock	...	.011
	16 hours after shock	...	.011
	24 hours after shock	...	30.007
			30.011

As the average height of the barometer from some years of observation is 30.005, it follows that at the time of an average earthquake shock the barometer is a little above its average height. This is due to the circumstance that the winter months, December, January and February, when the barometer is above its monthly average, are more liable to shocks than other months of the year; and that the hours from 8 p.m. to 2 a.m., when the barometer is above its diurnal average, are similarly more liable to shocks than other hours of the day.

					Miles.
(2) WIND—	Day before shock	...		...	89
	Day of shock	...		...	77
	Day after shock	...		...	87

			Min.	Mean.	Max.
(3) TEMPERATURES—	Day before shock	...	70°.1	77°.7	87°.3
	Day of shock	...	70 .1	77 .6	87 .5
	Day after shock	...	69 .7	77 .3	87 .2

For the same reason that the barometer is a little above, the temperature is a little below the annual average, which is 78°.2. The day after a shock is a little cooler than the two preceding days, because it is more cloudy.

			Per cent.
(4) CLOUD—	Day before shock	...	32
	Day of shock	...	36
	Day after shock	...	41

			Total Fall on 26 days In.
(5) RAIN—	Before shock	...	0.63
	Of shock	...	0.74
	After shock	...	0.05

Having thus confirmed all the previous work, and having thus obtained the meteorological changes which accompany an average earthquake shock, we must now inquire into the connection between them.

Referring to the First Report, the difficulty may be stated in the following words :—" We might find an explanation of small movements of the air through the upheaval of large areas of the surface of the earth, in the same way that the sea is often disturbed; and these movements would be shown by the barometer: but how can any such action stop our strong sea-breezes? Let us again consider shock No. 9. The sea-breeze was blowing as usual during the morning with a velocity of about 10 miles per hour; at 3 p.m. it suddenly stopped, and a light air came down from the north! This was 14 hours before the shock."

The first matter for discussion is clearly the nature of the foundation on which the Island of Jamaica rests.

According to deep-sea soundings there is a submarine ridge which extends from Cape Gracios a Dios on the Mosquito Coast to Jamaica and Hayti. This ridge is about 2,000 fathoms above the bed of the Caribbean sea on the south-eastern side of Jamaica, and the "Bartlett deep" on the northern side; and it is about 800 fathoms below the surface of the sea. From this ridge certain elevations rise; and the tops of these elevations form the Gorda, Rosalind, and Pedro Banks, and the Islands of Jamaica and Hayti.*

Jamaica is therefore part of a submarine mountain chain, which is about 900 miles in length and 150 miles in breadth; and the Blue Mountain Peak in Jamaica, the highest point in the chain, rises 24,000 feet, or somewhat less than five miles, above the ocean bed.

The slope of the ridge is therefore only 1 in 15: and unless a rough sketch be made of a section of the ridge at right angles to its direction, and through its highest point, it will be difficult to grasp the small amount of slope thus indicated, and certain consequences which we have now to point out.

Suppose that the subterranean forces underneath Jamaica were gradually to upheave the surface 2 or 3 feet in the course of a few hours; then would the sea which surrounds Jamaica be also gradually raised, and at the same time slowly flow away from the elevated coast; and the atmosphere which rests on the land and sea would be similarly raised throughout its whole height, the air would flow off rapidly from the centre of the elevation, and the barometer would fall.

The extent of the fall of the barometric column may be indicated by stating that 0.001 in., of the barometric balances 1 ft. of the atmospheric column in Jamaica; so that if 2 or 3 ft. of air flowed away, the barometer would fall 0.002 or 0.003 in.

Conversely, if the surface were to subside 2 or 3 ft. in the course of a few hours, the sea would gradually flow towards the depressed shores; the air would flow in from all sides towards the centre of depression; and the barometer would rise 0.002 or 0.003 in.

All this will be readily granted were the air at rest; but if our usual easterly winds were flowing over Jamaica at the rate of 12 miles an hour, such trivial disturbances would apparently be swept away; and we have therefore to show, as already said, how such a small upheaval could check our strong easterly breezes.

In Weather Report No. 69 it was shown that certain hydro-dynamic relations between wind-velocities and gradients agreed with the observations made during the Jamaica Cyclone of Aug. 20th, 1886, as closely as the nature of the observations would permit. From these relations we learn that when the air flows directly across a series of isobars but slightly curved, a change of the barometric

* The ridge is connected at Hayti with a sub-marine plateau which contains Cuba, the Bahama Islands, and Florida; and its extension eastwards and southwards is marked by Porto Rico and the Windward Islands.

gradient of 0.00045 in. per mile would reduce the velocity of the flowing air from 12 to 4 miles an hour;* and from what has been already said, this change of barometric gradient corresponds to a change of level of the atmospheric strata of $5\frac{1}{2}$ inches per mile. That is to say if the ground and all the atmospheric strata were upheaved so as to alter their slope $5\frac{1}{2}$ inches per mile, not only would the sea breeze at the surface be reduced to about 4 miles an hour, which is hardly noticeable, but as the sea-breeze does not extend upwards more than one or two thousand feet, such a change of gradient would cause the upper strata of the atmosphere to flow away readily, and thus by friction to bring the lower strata to rest, and in a somewhat fitful manner to produce a calm at the surface of the earth.

The consequence of a small upheaval would therefore not only allow a small amount of air to flow off from the part upheaved and the barometer to fall, but by the corresponding change of level the atmosphere would be affected throughout its entire height, the wind at the surface of the earth would be checked, and the upper strata would flow off horizontally

Again as these strata of air flowed off, they would produce thin sheets of horizontal clouds, the *stratus* of Meterology; and finally, from the manner of the formation of these clouds they could let fall little or no rain.

We have thus arrived at the explanation required; subterranean forces are continually at work below the surface of the earth; and no doubt small vertical movements often occur unnoticed; at times, however, small and sudden dislocations are produced among the lower geological strata or unstratified rocks; and only when an earthquake shock jars the surface of the ground is our attention drawn to the accompanying meteorological effects produced by the same cause, namely, slow vertical movements, first of subsidence and then of upheaval.

Changes in the sea-level on our shores would no doubt be generally observed about the time of our earthquake shocks if we had the means of registering them;† and it is a matter of history that during great earthquakes here and elsewhere, the undulations of the sea produce appalling effects on its shores. Moreover the rise and fall of water in wells and springs assure us that, all the world over, earthquakes are intimately connected with the gradual subsidence and upheaval of the land itself.

Again the checking of the wind and the consequent calm about the time of an earthquake is also a matter of history, and as already stated in the first Report, it has been noticed in Jamaica for at least 200 years.

As far therefore as we are able to judge our earthquake system will be found to hold good where no volcanoes are near at hand to modify the operations, to discharge fiery gases from their craters, to pour molten lava over the crest of their cones, and so to relieve the subterranean forces.

We have thus endeavoured to sketch out the principles which connect earthquakes with meteorological changes in Jamaica; but many exceptions must present themselves to the minds of our readers: for instance, although no doubt the strains reach their maxima at the times of greatest upheaval, yet the dislocations which produce the shocks may occur at any time during the slow movements of the ground.

Again, if the subsidence and upheaval were caused by forces only a few miles below the surface, the land alone might be affected, and the sea might be undisturbed; and vice versâ. In the former case, the barometer, in the latter case, the sea upon our shores, would rise and fall.

Again, the barometer cannot measure the amount of subsidence and upheaval in the case of any particular shock, for the simple reason that the air is elastic and obeys any impulse only too readily.

Again, the small upheaval of 2 or 3 ft. at the time of an average shock, and the gradient required to produce a calm, limit the upheaval to a small part of the island only; and this is true; for although a shock may be felt all over the island in consequence of its intensity, yet we seldom or never have a number of shocks at different parts of the island at much the same time; but on the other hand we often have two or three shocks at the part upheaved at intervals varying from 1 to 6 hours or more.

Lastly, during the subsidence, and when the air flows in from all sides, some atmospheric disturbance might be expected besides a gradual rise of the barometer; gusts of wind alternating with calms have been noticed in Jamaica; but the most satisfactory and convincing note comes from England, where clouds which had been previously undisturbed were seen to be agitated, and to whirl round and round, a short time before a local shock of earthquake occurred.‡

In conclusion, attention must be drawn to the desirability of recording the movements of the sea on the shores of Jamaica; of course Port Royal is the most suitable place for the erection and registration of a tide-gauge; and the co-operation of the Naval authorities must be asked: and while special care will be taken at Kingston to record the movements of the air, it is greatly to be hoped that some means at least will be taken at Port Royal to record the movements of the sea; and then after a few more years of observation a third Report may deal with the connection between these slow movements of the land, of the air, and of the sea.

Neither is the subject void of interest; what can be grander than the calm of nature before an earthquake? The winds are hushed, animals and birds feel the slow movements and display their anxiety, and a solemn silence settles over the land perhaps devoted to destruction.

But should tide or water-gauges be found to work in harmony with highly sensitive barometers, the telegraph might be used in Countries liable to destructive earthquakes to warn the Towns of the slow movements of the ground thus indicated.

MAXWELL HALL.

Montego Bay, March, 2nd 1887.

* For 12 miles an hour the gradient is 0.00067 in. per mile: for 4 miles an hour the gradient is 0.00022 in. per mile.
† The water rose 18 inches in Kingston Harbour 6 hours after shock No. 9.
‡ Nature.