(39.) Buller, " Supplementary Volumes to the Birds of New Zealand."
(40.) Sandager, Trans. N.Z. Inst., vol. xxviii, p. 8.
(41.) Yate, " Account of New Zealand," p. 65.
(42.) Buller, " History of Birds of New Zealand."
(43.) Hutton and Drummond, " Animals of New Zealand," p. 120.
(44.) Fulton, Trans. N.Z. Inst., vol. xxxvi, p. 133.
(45.) Newton, " Dictionary of Birds," pt. i, p. 120.
(46.) Hume, " Birds of India," p. 140.
(47.) Potts, Trans. N.Z. Inst., vol. xxiii, p. 219.
(48.) *Ibis*, 1902.

Art. L.—*The Remarkable Rainfall and Meteorology of Waihi.*

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[*Read before the Auckland Institute, 22nd November*, 1909.]

Before entering into the subject-matter of this paper it will be necessary to refer to the peculiar topographical features of the Waihi district.

Waihi, which is situated on a more or less circular basin, about five miles in diameter, and averaging about 350 ft. above sea-level, lies at the western end of the Bay of Plenty. It is flanked seawards by the high abruptly rising coastal range, and to the west-south-west by the Cape Colville Range, which has its highest point in Te Aroha Mountain. Irregular ridges bound the basin to the south-east, and on the north-west a moderately high range, of irregular features, completes an apparent circle. Several isolated hills of moderate height, mostly described as " barren clay hills," and bearing evidences of the denuding effect of strong westerly winds and heavy rainfall, rise from the plain.

In a meteorological sense, the most notable feature of Waihi is not so much the frequency as the intensity of its rainfall. It will be the endeavour of the writer to throw some light on the agencies which bring about such remarkable records.

First in importance are those cyclones which come—(1) from the neighbourhood of Norfolk Island, and, passing eastward of North Cape, pass to the northward of East Cape ; (2) approaching East Cape from about north, but passing eastward of it, and when southward of it take a more south-east direction. As a rule, the track of these systems is well to seaward, but sufficiently close to cause very heavy rainfalls. Occasionally the track is across the Island, between Taupo and East Cape : this movement is accompanied by heavy easterly gales, severe backing winds, and intense rainfall. This forward movement across the island, however, is the exception, for the physical features of the land seem to have the power of deflecting these storms to seaward. The passage of a cyclone to the east is, as a rule, not accompanied by heavy southerly backing winds, for Waihi is well sheltered in this respect by the high country to the south and south-east.

Again, a common feature of the meteorology of this locality is the junction of a westerly wave depression with a cyclone, with the usual effect

that the wind-force of both systems is neutralised. This fusion is an important factor for heavy rainfall, and will be referred to in greater detail.

The easterly winds of an energetic anticyclonic system often bring heavy falls, for the moisture which they gather from the sea is deposited on the windward slopes of the ranges.

Heavy rain from the west is the exception, for the winds of a depression passing westward appear to have deposited much of their moisture on the high country of the western Waikato and on the windward slopes of the Te Aroha Range.

Another feature well known in the meteorology of the Dominion is the passage of a series of wave-pressures from the west. These waves bring remarkably changeable weather. The winds range from between west-north-west and north-west and west and back again towards the west, these changes sometimes occurring rapidly. Pressure is also oscillatory, sometimes in a marked degree.

Having described the systems which govern the climate, and the topographical features, further and detailed reference will be made to the intense nature of the rainfall.

The records have been criticized with some scepticism, and it is well to record the fact that for some years two gauges have been exposed—an ordinary funnel-and-bottle pattern, and a Lander and Smith automatic recording, eight-day-clock movement—one gauge checking the other.

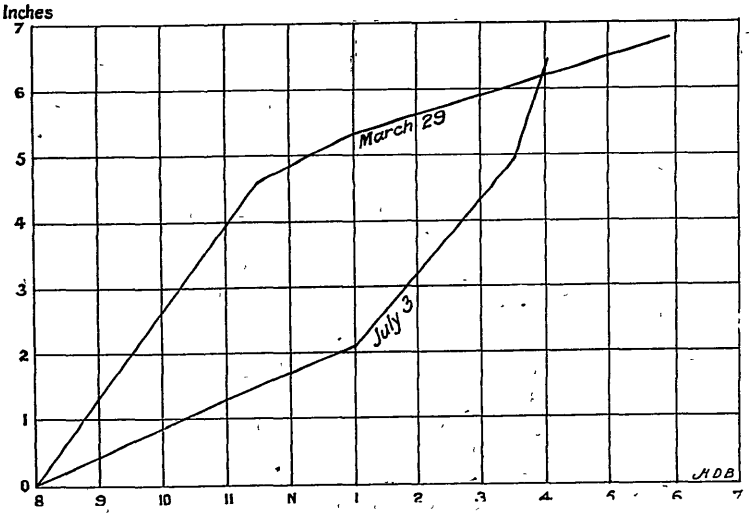
The most prolonged precipitation recorded since 1898, when the observations commenced, was that of January, 1907, when 21½ in. fell in nine days. The records of the Meteorological Office showed the passage of a cyclone of great area from the neighbourhood of Norfolk Island, between the North Island and the Kermadecs. The cyclone had two minima, and great floods were experienced over the Auckland Province—Waihi's total for the month was 25 in., the biggest individual total for that notable period; Tauranga's total was 20·94 in.; Auckland's approximately 8 in.

The two most remarkable falls recorded locally occurred during the present year, and invite special comment. The first was recorded to 29th March, and the second to 3rd July. The rates of fall are shown in the diagram on p. 410.

In the first instance, the fall of 29th March was due to the passage of a cyclone of unusual extent, which approached East Cape from about north, and, traversing the east coast of both Islands, caused very heavy falls. The barogram of the 29th was remarkable for its waviform trace, and it may be that the air-waves propagated by such a disturbance can be transmitted a very considerable distance. The rainfall was intense within certain limits, as the rates show; the heaviest precipitation appears to have been confined to the coastal hills. A visit to the coast soon afterwards showed the tremendous nature of the fall, which must have been double that which was recorded at the station, three miles and a half distant. In one particular valley the destruction was unique. Residents state that the water came down in a wall 20 ft. high, bringing with it large trees with the soil adhering to the roots; large boulders, one weighing over a ton; and thousands of yards of soil and gravel. Most of the *débris* was carried right down to the sandhills, through which the stream had cut a fresh outlet. It was evident that the damming-up of watercourses and the subsequent release of the obstructions was not the sole cause of the remarkable damage: eye-witnesses state that the rain was flowing down the slopes in cascades. At 1 p.m. there was a single electrical discharge on the coastal range of

the nature of a thunderbolt. The shock was severe, and the phenomenon would appear not to have been connected with the "trough" of the cyclone, but to have been due to an atmospheric upheaval on a large scale, the outcome of excessive wave-motion. It is probable that some of the remarkably intense rainfall recorded on this date was due to "cloud-bursts." The sky of the previous day indicated considerable wave-motion — cirro-stratus (pallium) overlying long lines of waviform cumulo-stratus, merging into patches, at intervals, of very pronounced "pocky" clouds, said to be an infallible sign of storm in the Orkneys.

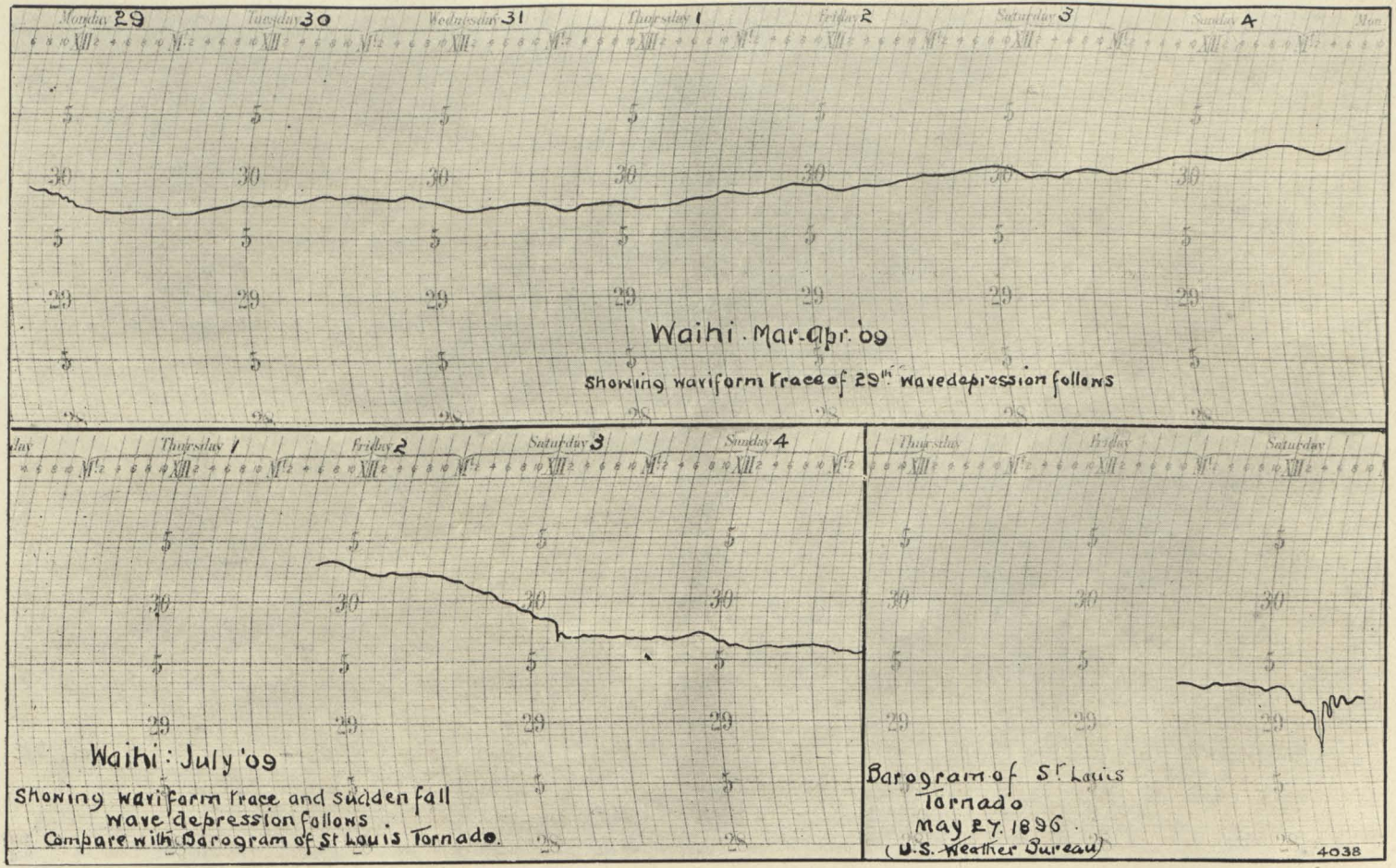
The storm of the 3rd July was still more remarkable, and was associated with the heaviest easterly gale recorded since 1898. The barographic curve



Graph showing Rates of Precipitation at Waihi on 29th March and 3rd July, 1909.

also displayed wave-motion, and depicted the sudden drop in pressure which occurred about 3 p.m.—a decline of fifteen-hundredths in fifteen minutes. This movement was accompanied by wind backing to south-east, and the most intense rain recorded here, 1·45 in. falling in thirty minutes. The barogram suggests the formation of a small "satellite," offset from the parent system, apparently tornadic in nature. The passage of this system was followed by improving conditions, and by nightfall the clouds changed movement from north, again evidencing the fusion of a westerly wave-depression with the low pressure. The glass showed no inclination to recover until the 5th, and anticyclonic pressure was not restored till the 7th. If cyclonic formation is a true circle, then the barometer should regain the height from which it had fallen, and it is evident when this movement is unduly retarded that there must be more than one low-pressure system existent.

Before concluding, reference is made to a remarkable cigar-shaped cloud which forms over Waihi during high west-south-west winds, sometimes five miles in length. This cloud, which has been observed by Davis, Hann, and others elsewhere, and which is described as analogous to the "standing wave" produced by running water on the surface of shallow and rocky streams, appears to be in continual motion, but in reality is stationary,


Monday 29
Tuesday 30
Wednesday 31
Thursday 1
Friday 2
Saturday 3
Sunday 4
Waihi. Mar-Apr. '09
Showing wariform trace of 29th wavedepression follows
Thursday 1
Friday 2
Saturday 3
Sunday 4
Waihi: July '09
Showing wariform trace and sudden fall
wave depression follows.
Compare with Barogram of St Louis Tornado.
Thursday
Friday
Saturday
Barogram of St Louis
Tornado
May 27. 1896.
(U.S. Weather Bureau)
4038

and forms to leeward of the Te Aroha Range. It is often a remarkable spectacle in an otherwise cloudless sky.

Reference is also made to the occurrence of "foehn"-like winds from the north-west in early spring. It is not certain whether these winds blow in front of an advancing disturbance or whether they are due to the influence of high country. The ranges to the north-west are of only moderate height. Certain it is that these winds bring a marked increase in temperature, and have the parching characteristics of the foehn.

CONCLUSION.

It would appear that the cause of the remarkable rainfall of Waihi may be found in—(1) its nearness to the ocean; (2) its situation as regards the track of cyclonic storms; (3) its topographical features; (4) Nos. 2 and 3 operating in combination.

Hann has shown how mountainous districts often produce "islands" of heavier and more frequent rainfall, and that the precipitation does not begin at the foot of the ranges but at some distance therefrom: local observations confirm this.

It may be well to note that Athenree, situated five miles distant to the south-east, almost invariably recorded smaller rainfalls during the passage of a storm. This feature can, no doubt, be accounted for when it is stated that the slope of the land from the sea at this latter station is small, and it presents no bold features.

Frequent reference has been made to the passage of wave-depressions* in conjunction with cyclones as a factor for heavy precipitation. Helmholtz† has found that atmospheric waves or undulations may exist on a most gigantic scale, in which the wave-length is several kilometres, and so great is the amplitude that when they occur at elevations of one or even more kilometres above the earth's surface their action is felt at the ground. This explanation would appear to account for the waviform barographic trace hereinbefore referred to, and which is generally coincident with intermittent wind-gusts and heavier bursts of rain. Since the upheaval of air in the truly mountainous waves must amount to hundreds of metres, causing a mixture of air-layers, it is easy to conceive that precipitation would occur; and this impulse would accelerate and extend higher upwards the movement already begun.

It may be that the passage of a wave-depression concurrently with a cyclonic area would set up wave-interferences attended with "breaking" phenomena. Helmholtz explains that the counterparts in the air of breaking spraying water-waves would cause a mixture of air-layers. Hann‡ has shown how saturated layers of air, being forced to rise, expand, and by expansion become cooled below the dew-point. If this process, already begun, is accelerated, further cooling would result, and it is easy to conceive of the enormous quantities of rain which may fall under these conditions.

EXPLANATION OF PLATE XXXIX.

The upper part of the plate is the barogram for the week ending 5th April, 1909. In the lower part of the plate the Waihi record of 3rd July, 1909, shows similar waviform trace and sudden fall to that of the St. Louis tornado of 27th May, 1896.

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* Captain Edwin, Trans. N.Z. Inst., vol. xxxvii, p. 557.
† Waldo, "Modern Meteorology," p. 335.
‡ Hann, "Handbook of Climatology."