THE USU-SAN ERUPTION AND THE EARTHQUAKE AND ELEVATION PHENOMENA.

III.

Results of Precise Levelings in 1905-1919, with Accounts of the Observations relating to the Level Change of the Lake of Toya.

By

F. Omori, Sc.D.,

Member of the Imperial Earthquake Investigation Committee.

With Plates X–XVII.

1. Introduction. The Usu-san, which stands on the north-eastern coast of the Volcano Bay (in Hokkaido) and separates it from the lake of Toya, is a small mountain, only 736 m.* in height, whose base covers about 35 sq. km. The volcano is, however, active in eruptive manifestations, and seems to have experienced upheavals on some of the former outbursts ; the formation of the principal dome, the O-Usu, evidently of no very old date, being ascribed by some authorities to the eruption in 1853. The principal phenomenon in the Usu-san eruption of 1910 consisted in the elevation of the region about the volcano, culminating in the formation of the New Mountain at the northern base bordering the lake of Toya. Even at the coast of the Volcano Bay, on the opposite side, the elevation reached nearly 1 foot. (See the Bulletin, Vol. V, Nos. 1 and 2.) It was desirous to ascertain the

* Height of the O-Usu dome, according to the new Geological Survey map.

TABLE I. Height of the Bench Marks in 1905, 1911–13, and 1919.

In the survey of 1912, 1913, and 1919, the B.M. No. 7191 is taken as the fixed point.
„ 1911, „ No. 7190 „ „

Bench Mark. Locality.		No.	Height. 1905	1911	1912	1913	1919
[Abuta Village District.]			m.	m.	m.	m.	m.
ピハオク	Abuta, Biwaok.	6596	49.0857	50.2574	50.2340	50.2259	50.2057
床丹	„ Tokotan.	6597	150.6192	150.5629	150.5241	150.5273	150.5255
	„ „	6598	93.0124	95.4542	95.4125	95.4111	95.3932
プオシマ	„ Puoshima.	6599	86.3755	86.3569	86.3403	86.3519	86.3540
ポロモイ	„ Poromoi.	6600	88.6877	88.6891	88.6675	88.6843	88.6848
„	„ „	6601	86.1620	86.1658	86.1393	86.1568	86.1558
オオザク	„ Oozak.	6602	86.8139	86.8168	—	—	86.8103
向洞爺	Muko-Toya.	6603	86.2596	86.2663	—	—	86.2597
„	„	6604	—	—	—	—	85.5009
チヤスナイ	Abuta, Chasnai.	7190	140.6111	104.6111	—	—	—
クリヤ	„ Kriya.	7191	60.2509	60.2465	60.2509	60.2509	60.2509
フレナイ	„ Frenai.	7192	2.6572	2.6346	2.6372	2.6337	2.6299
床丹	„ Tokotan.	VI	3.5676	3.9296	3.9248	3.9169	3.9027
オモナイ	„ Omonai.	7193	9.5764	—	9.7852	9.7804	9.7671
[Daté Village District.]							
有珠	Usu, Sneushima.	7194	3.7524	—	3.9553	3.9462	3.9282
„	„	7195	30.0242	—	30.1671	30.1651	30.1495
長流, オサルベツ	Osarubets.	7196	6.4822	—	6.5629	6.5641	6.5458
西紋鼈タラヤマ	Tarayama.	7197	4.2696	—	4.2857	4.2927	4.2710
„ 裏濱	Urahama.	7198	—	5.5162	5.5217	5.5270	5.5040
シヤシチセ	Hi. Moubets,	7199	14.0073	—	—	14.0194	14.0026
ハギハラ	„	7200	14.1432	—	—	14.1556	14.1371
マレツプ	Marep.	7201	11.9577	—	—	—	11.9483
オコンポニベ	Okonbonibe.	7202	2.8598	—	—	—	2.8539
„	„	7203	2.3877	—	—	—	2.3827

TABLE II. Height Variations of the Bench Marks, between the years 1905 and 1919.

(Referred to the B.M. No. 7191 as fixed point.)

Bench Mark. No.	Height Variation.					
	1905 to 1911	1905 to 1912	1912 to 1913	1913 to 1919	1905 to 1919	1911-12 to 1919
[Abuta Village District.]	m.	m.	m.	m.	m.	m.
6596	+ 1.1717	+ 1.1483	− 0.0081	− 0.0202	+ 1.1200	− 0.0422
6597	− 0.0563	− 0.0951	+ 0.0032	− 0.0018	− 0.0937	− 0.0202
6598	+ 2.4418	+ 2.4001	− 0.0014	− 0.0179	+ 2.3808	− 0.0424
6599	− 0.0186	− 0.0352	+ 0.0116	+ 0.0021	− 0.0215	+ 0.0032
6600	+ 0.0014	− 0.0202	+ 0.0168	+ 0.0005	− 0.0029	+ 0.0043
6601	+ 0.0038	− 0.0237	+ 0.0175	− 0.0010	− 0.0062	+ 0.0010
6602	+ 0.0029	—	—	—	− 0.0036	—
6603	+ 0.0067	—	—	—	+ 0.0001	—
6604	—	—	—	—	—	—
7190	0.0000	—	—	—	—	—
7191	− 0.0044	0.0000	0.0000	0.0000	0.0000	0.0000
7192	− 0.0722	− 0.0200	− 0.0035	− 0.0038	− 0.0273	− 0.0082
VI	+ 0.3620	+ 0.3572	− 0.0079	− 0.0142	+ 0.3351	− 0.0267
7193	—	+ 0.2088	− 0.0048	− 0.0133	+ 0.1907	− 0.0181
[Daté Village District.]						
7194	—	+ 0.2029	− 0.0091	− 0.0180	+ 0.1758	− 0.0271
7195	—	+ 0.1429	− 0.0020	− 0.0156	+ 0.1253	− 0.0176
7196	—	+ 0.0807	+ 0.0012	− 0.0183	+ 0.0636	− 0.0171
7197	—	+ 0.0161	+ 0.0070	− 0.0217	+ 0.0014	− 0.0147
7198	—	—	+ 0.0053	− 0.0230	—	− 0.0172
7199	—	—	+ 0.0121	− 0.0168	− 0.0047	− 0.0037
7200	—	—	—	− 0.0185	− 0.0061	—
7201	—	—	—	—	− 0.0094	—
7202	—	—	—	—	− 0.0059	—
7203	—	—	—	—	− 0.0050	—

course of the height variation subsequent to the eruption in question, and through the liberality of the Imperial Academy and the good will of the Military Survey, the necessary leveling work has been carried on in June-Aug., 1919, a new height examination having been made of the 23 bench marks over the distance of 44 km. along the coast of the Volcano Bay and across to the west coast of the lake of Toya. Previous to 1919, the height re-examination had been executed partially along the lines of precise leveling under consideration during the three successive years 1911 to 1913. The results of the different surveys are given in Tables I and II.

2. Height difference between 1905 and 1919. Of the different bench marks taken in our consideration those furthest from the centre of the Usu-san, on whose northern slope the New Nountain is situated, are Nos. 6604, 7191 (or 9190), and 7203, as follows:—

B.M. No. 6604,.....9½ km. to the N.7° W., on the N.W. coast of the lake.

,, 7191,.....7½ km. to the N.75°W., on the coast of the Volcano Bay.

,, 7203,.....17 km. to the S.40°E., on the coast of the Volcano Bay.

The height difference along the leveling lines about the Usu-san between 1905 and 1919, respectively 5 and 9 years before and after the eruption, is shown in Table III, there being no material difference in the result whichever of the three above mentioned bench marks be taken as the fixed point. Moreover the amount of the change was very slight for the 5 bench marks Nos. 6600 to 6604 on the west coast of the Toya lake and for the 7 bench marks Nos. 7197 to 7203 on the coast of the Volcano Bay. Marked level change was thus limited to the Usu-san district about 5 km. in

TABLE III. Height Difference of the different Bench Marks, between the years 1905 and 1919.

Bench Mark. No.	Height Change between 1905 and 1919.		Bench Mark. No.	Height Change between 1905 and 1919.	
	B.M. No. 7203 as fixed point.	B.M. No. 7191 as fixed point.		B.M. No. 7203 as fixed point.	B.M. No. 7191 as fixed point.
	m.	m.		m.	m.
7191	+ 0.005	0.000	6596	+ 1.125	+ 1.120
7192	− 0.022	− 0.027	6597	− 0.089	− 0.094
VI	+ 0.340	+ 0.335	6598	+ 2.386	+ 2.381
7193	+ 0.196	+ 0.191	6599	− 0.017	− 0.022
7194	+ 0.181	+ 0.176	6600	+ 0.002	− 0.003
9195	+ 0.130	+ 0.125	6601	− 0.001	− 0.006
7196	+ 0.069	+ 0.064	6602	+ 0.001	− 0.004
9197	+ 0.006	+ 0.001	6603	+ 0.005	0.000
9198	—	—	6604	+ 0.008	+ 0.003
7199	0.000	− 0.005			
7200	− 0.001	− 0.006			
7201	− 0.004	− 0.009			
7202	− 0.001	− 0.006			
7203	0.000	− 0.005			

radius, bounded on the east by the Osaru river, and on the west by the line connecting the three bench marks Nos. 6599, 6597, and 7192, which nearly coincides with the shortest distance between the lake and the bay. Only the three last mentioned bench marks indicated definitely the depression of the ground, which, taking the B.M. No. 7203 at the S.E. end as the fixed point, amounted to 0.017; 0.089, and 0.022 m. respectively. On the contrary, the other bench marks at the western base and all those at the southern base of the Usu-san were considerably elevated; the amount of the change being specially marked and

respectively equal to 1.125 and 2.336 m. in the cases of B.M. No. 6596 situated 2 km. to the W., and B.M. No. 6598 about 4 km. to the W.S.W., of the New Mountain. Again, 2 km. to the E. of the latter, and in front of the school house at West Kohan, the lake coast was elevated 1.3 m. approximately. (See the Bulletin, Vol. V.) At the northern slope base of the New Mountain, which

TABLE IV. Height of the Bench Marks in Different Years.

(Referred to B.M. No. 7191 as fixed point.)

Group.	B.M.	1905	1911	1912	1913	1919
		m.	m.	m.	m.	m.
	6598	93.0124	95.4586	95.4125	95.4111	95.3932
A	6596	49.0857	50.2618	50.2340	50.2259	50.2057
	VI	3.5676	3.9340	3.9248	3.9169	3.9027
	6597	150.6192	150.5673	150.5241	150.5273	150.5255
B	6599	86.3755	86.3613	86.3403	86.3519	86.3540
	7192	2.6572	2.6390	2.6372	2.6337	2.6299

TABLE V. Height Variation* of the Different Bench Marks.

Group.	B.M.	(a) 1905 to 1911	(b) 1911 to 1912	(c) 1912 to 1913	(d) 1913 to 1919	(e) 1911 to 1913	(f) 1911 to 1919
		m.	m.	m.	m.	m.	m.
	6598	+ 2.4462	− 0.0461	− 0.0014	− 0.0179	− 0.0475	− 0.0654
A	6596	+ 1.1761	− 0.0278	− 0.0081	− 0.0202	− 0.0359	− 0.0561
	VI	+ 0.3664	− 0.0092	− 0.0079	− 0.0142	− 0.0171	− 0.0313
	6597	− 0.0519	− 0.0432	+ 0.0032	− 0.0018	− 0.0400	− 0.0418
B	6599	− 0.0142	− 0.0210	+ 0.0116	+ 0.0021	− 0.0094	− 0.0073
	7192	− 0.0182	− 0.0018	− 0.0035	− 0.0038	− 0.0053	− 0.0091

* The difference is positive (+) for the height increase, and negative (−) for the height decrease.

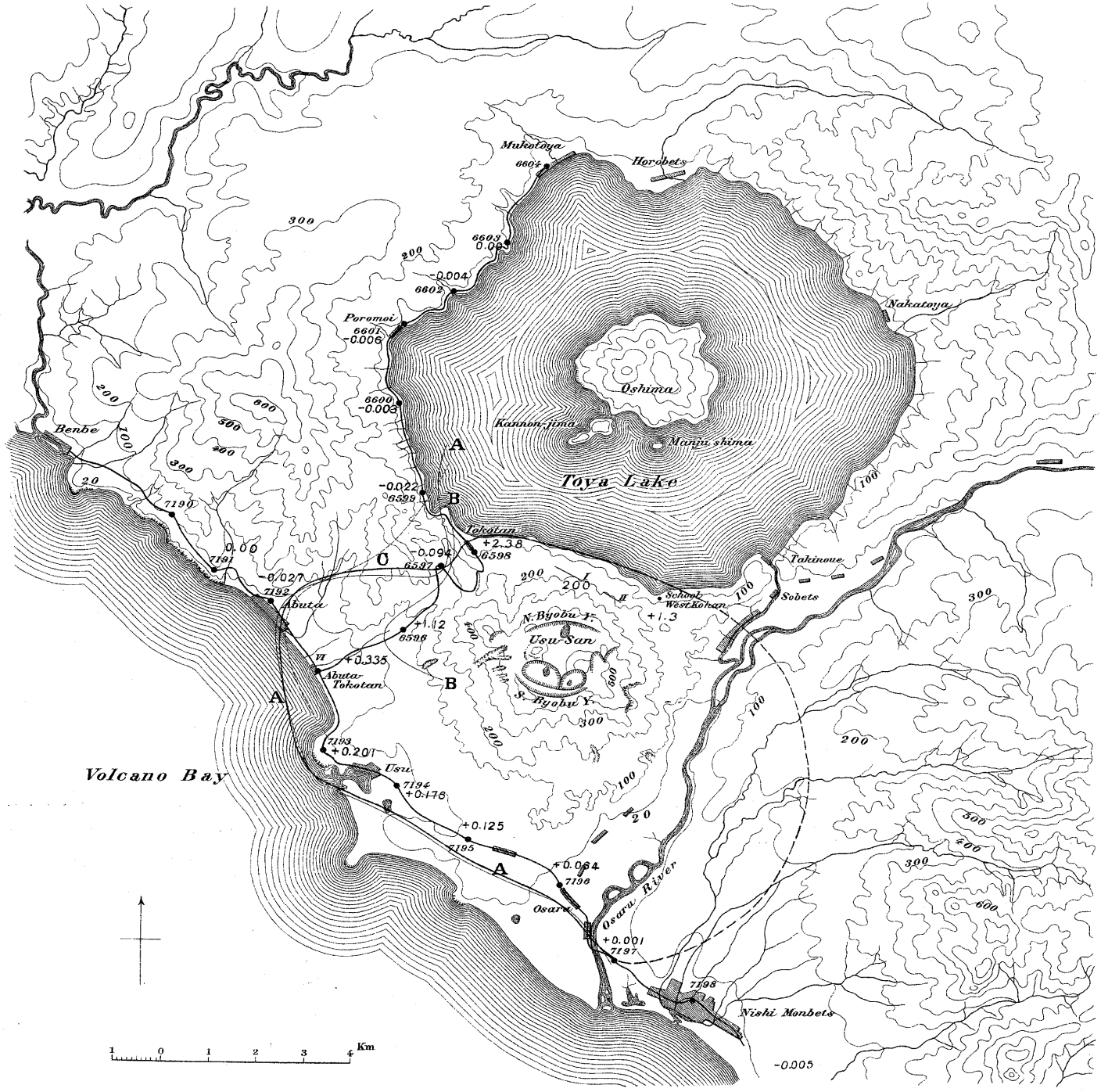


Fig. 1. Map showing the Height Difference in the Usu-san District between 1905 and 1919, respectively 5 years before and 9 years after the Eruption of 1910.

The red closed curve is the boundary of the elevated region. The red figures indicate the amount of change of the bench mark heights in 1919 relative to 1905, plus (+) when augmented and minus (−) when lessened.

Town or village.

Line of precise levelling and bench marks.

I, II are the Dislocation Lines of the "New-Mountain,"

Contour lines, which relate to the topography before the eruption, are given for heights of 20 m., 100 m., 200 m., 300 m., etc. above sea-level.

The two thin black curves A and B relate to the comparison of the bench mark heights in 1911–1912 with those in 1905, being respectively the line of no level change and the line of I metre elevation before and after the eruption of 1910. C is the line of no level change between 1911 and 1912.

seems to be the result of a great local upheaval, essentially with the pivot axis situated on, and parallel to the shore line, a strip of the land along the lake was depressed to the maximum width of about 35 m., the coast itself having been submerged to the maximum depth of about 12 feet.

As will be seen from fig. 1, the present condition of the change due to the eruptive activity of 1910 consists mainly in the elevation of the Usu-san region measuring about 10 km. in the N.W.–S.E. and $7\frac{1}{2}$ km. in the N.E.–S.W. direction. In this area the height change was most conspicuously displayed at the northern part, culminating in the formation of the New Mountain raised about 200 m., and in the second place, at the north-western part, where the B.M. No. 6598 was elevated about 2.4 m. Thus the depression of the ground, which was only definitely shown just outside the portions of a special elevation, may be regarded as the effect of a dislocation or fault produced about the latter.

3. Course of height variation between 1905 and 1919. The difference between the ground level in 1919 and that in 1905 considered in the preceding §, which was in the main produced at and immediately after the eruption of 1910, is the result of the addition of the small subsequent height changes. The approximate course of the variation of the latter during the interval of the 14 years in question can be clearly seen, amongst the others, of the two groups of the bench marks, (A) Nos. 6598, 6596, and VI, and (B) Nos. 6597, 6599, and 7192, which in 1910 suffered significant changes of elevation and depression respectively, and which were all surveyed in the 5 years, 1905; 1911; 1912; 1913; and 1919. According to Tables IV and V, in 1912 the different bench marks alike suffered some depression, which in the case of the A group progressed on uninterruptedly. It is true that the B.M. No. 6598,

which had experienced in 1910–1911 the great elevation of 2.4462 m., has also suffered the greatest depression of 0.0654 m. in the interval of the subsequent 8 years. But otherwise the total depression in 1919 relative to 1911 (*f*, in Table V) was not much dependent on the amount of the elevation or depression produced at the time of the eruption (*a*, in Table V). Thus the change on the latter occasion of the B.M. No. 6596 was an elevation of 1.1761 m. and that of the B.M. No. 6597 a depression of 0.0519 m.; and yet these two bench marks had in 1919 the total depressions respectively of 0.0561 m. and 0.0458 m., not very much different from the corresponding quantity for the B.M. No. 6598.

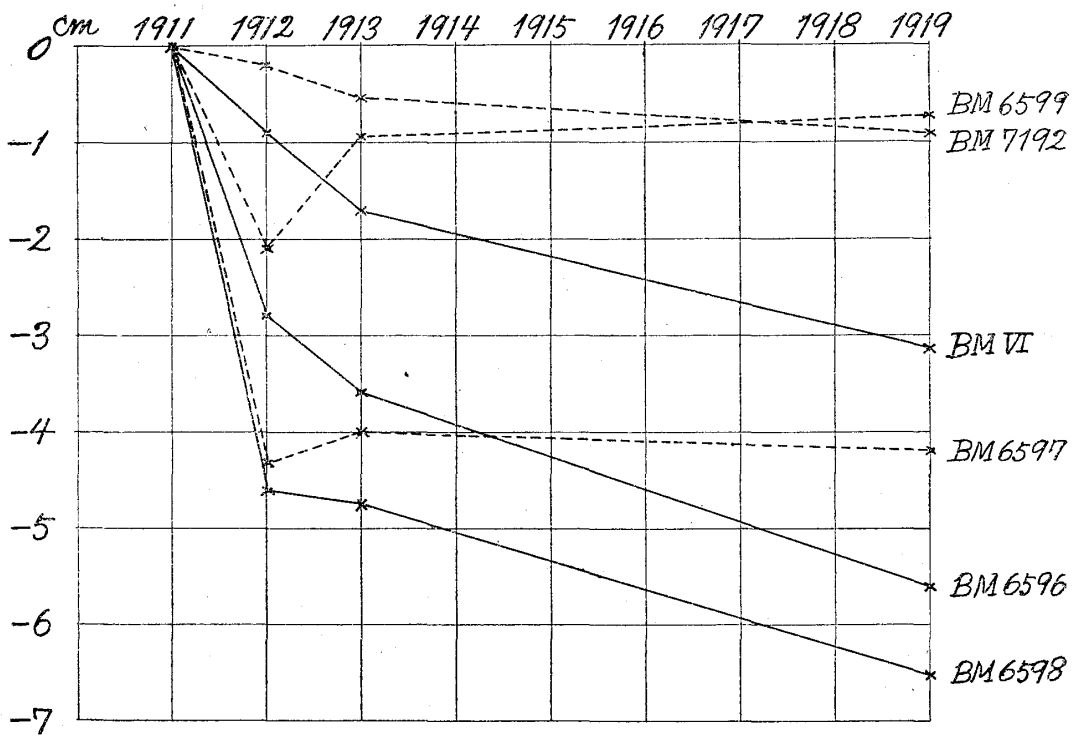


Fig. 2. Amount of the Height Change of the Different Bench Marks in 1912, and 1913, and 1919, referred to 1911.

Bench marks Nos. VI, 6596, and 6598 suffered marked elevations at the time of the Usu-san eruption (1910), while Nos. 6599, 7192, and 6597 indicated slight but distinct depressions on the same occassion.

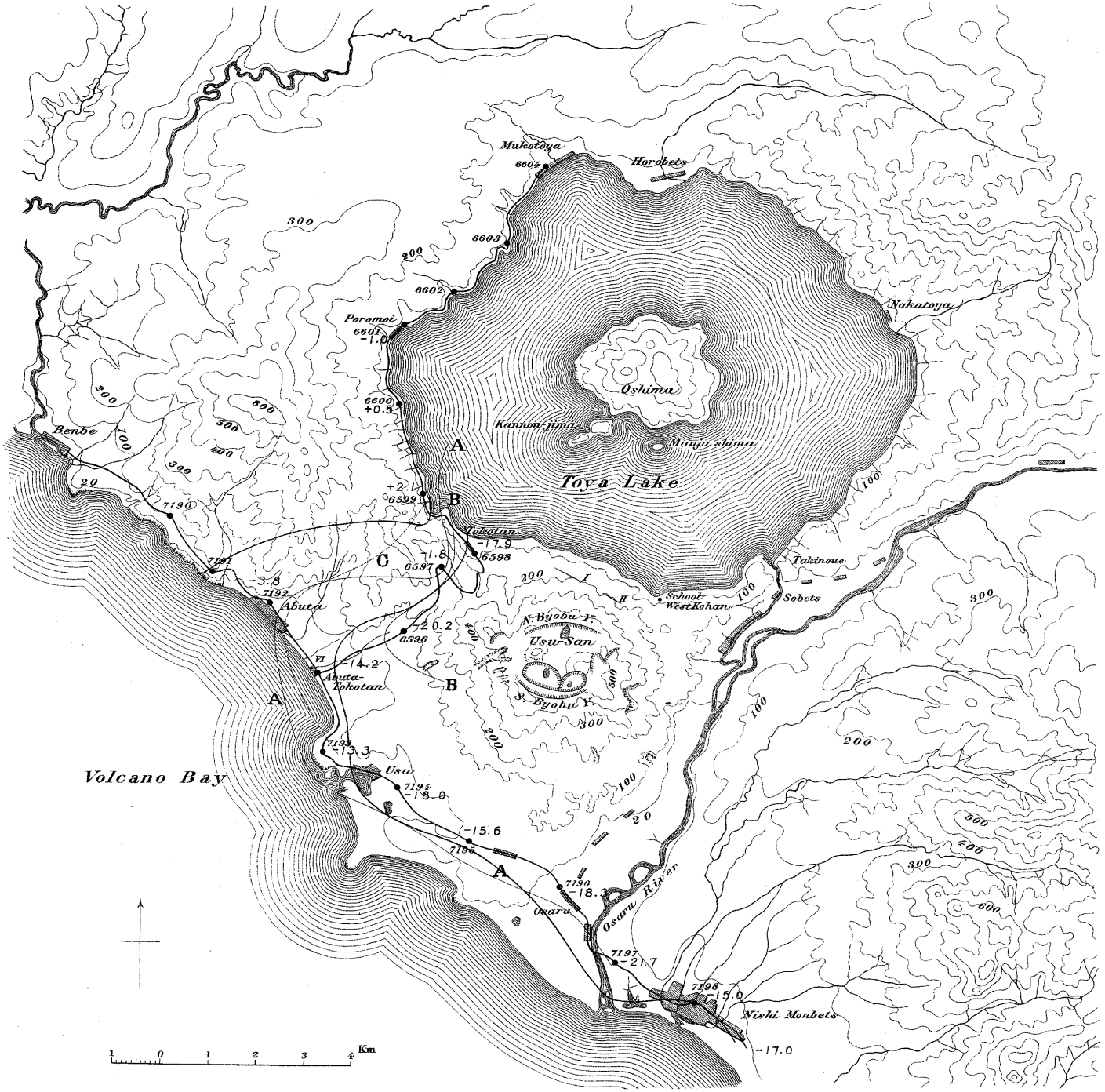


Fig. 3. Map showing the Height Difference in the Usu-san District between 1913 and 1919, respectively 3 and 9 years after the Eruption.

The outer (shorter) red curve is the line of no height change and the inner red curve is the line of 15 mm. depression of the ground in 1919 relative to 1913. The red figures indicate the change in the heights, plus (+) when augmented and minus (−) when lessened.

Town or village.

Line of precise levelling and bench marks.

I, II are the Dislocation Lines of the "New-Mountain."

Contour lines, which relate to the topography before the eruption, are given for heights of 20 m., 100 m., 200 m., 300 m., etc. above sea-level.

The two thin black curves A and B relate to the comparison of the bench mark heights in 1911–1912 with those in 1905, being respectively the line of no level change and the line of I metre elevation before and after the eruption of 1910. C is the line of no level change between 1911 and 1912.

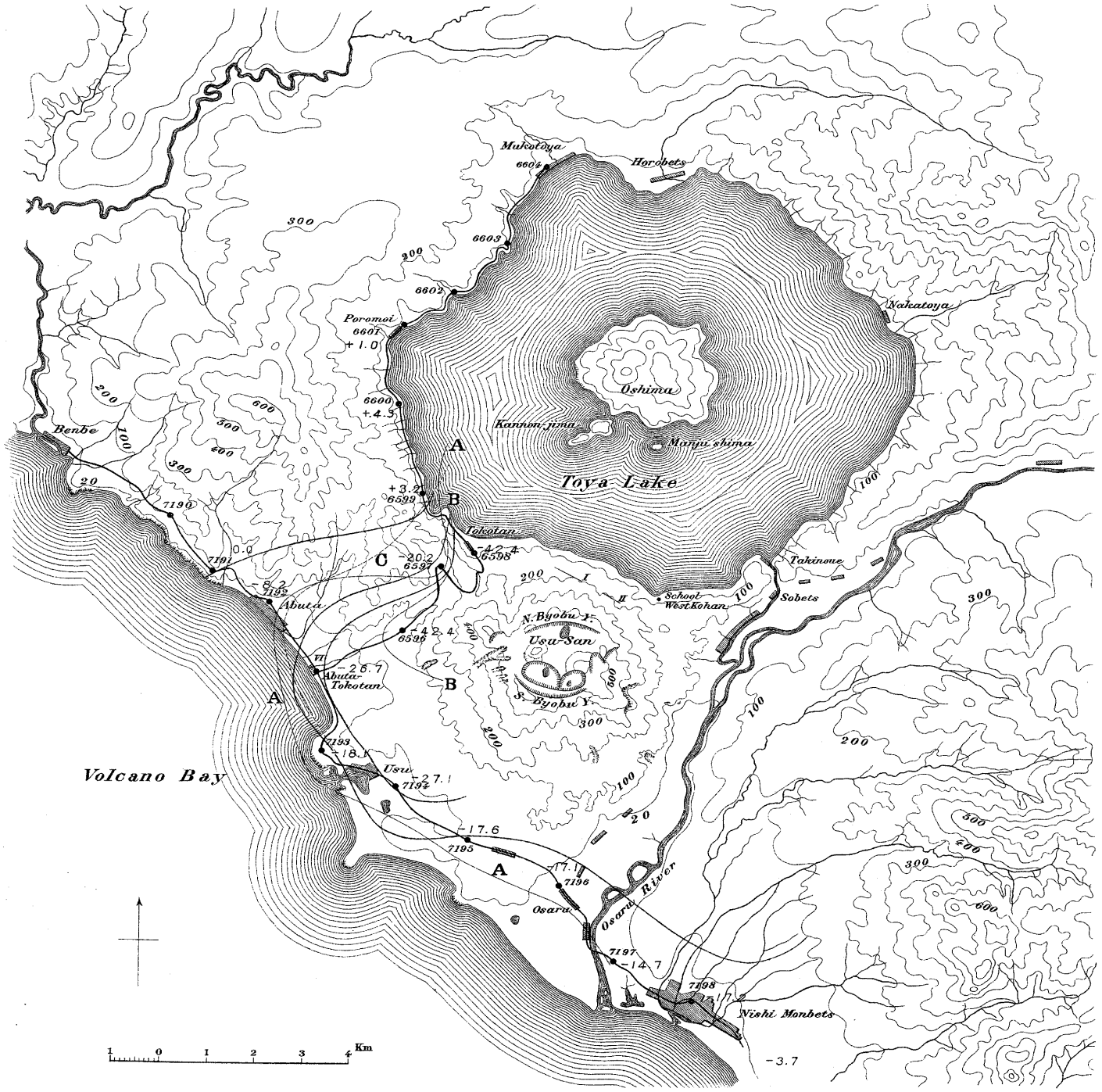


Fig. 4. Map showing the Height Difference in the Usu-san District between 1911–12 and 1919.

The outermost (short) red curve is the line of no change, and the two inner red curves are respectively the lines of 20 mm. and 27 mm. depressions of the ground in 1919 relative to the two years 1911 and 1912 taken together. The red figures indicate the changes in the height, plus (+) when augmented and minus (−) when lessened.

Town or village.

Line of precise levelling and bench marks.

I, II are the Dislocation Lines of the "New-Mountain."

Contour lines, which relate to the topography before the eruption, are given for heights of 20 m., 100 m., 200 m., 300 m., etc. above sea-level.

The two thin black curves A and B relate to the comparison of the bench mark heights in 1911–1912 with those in 1905, being respectively the line of no level change and the line of I metre elevation before and after the eruption of 1910. C is the line of no level change between 1911 and 1912.

TABLE VI. Height Variation of the Different Bench Marks between 1905 and 1912, and between 1913 and 1919.

Positive (+) when the height increases, and negative (−) when the height decreases.

[A] B. M.	1905—1912 (Elevation.)	1913—1919 (Depression.)	[B] B. M.	1905—1912 (Depression.)	1913—1919.
	m.	m.		m.	m.
6596	+ 1.1483	− 0.0202	7192	− 0.0200	− 0.0038
6598	+ 2.4001	− 0.0179	6599	− 0.0352	+ 0.0021
VI	+ 0.3572	− 0.0142	6600	− 0.0202	+ 0.0005
7193	+ 0.2088	− 0.0133	6601	− 0.0237	− 0.0010
7194	+ 0.2029	− 0.0180	6597	− 0.0951	− 0.0018
7195	+ 0.1429	− 0.0156			
7196	+ 0.0807	− 0.0183			
6197	+ 0.0161	− 0.0217			
7198	.....	− 0.0150			
7199	0.0000	− 0.0168			
7200	.....	− 0.0185			
Mean.	.....	**− 0.0172**	Mean.	.....	**− 0.0008**

The depression in 1912 relative to 1911, (*b*, in Table V), however, had, for the A group bench marks, a nearly constant ratio to the elevation at the time of the eruption (*a*), giving the mean value of 2.3%, as follows:—

B. M.	(a) Elevation. 1905—1911	(b) Depression. 1911—1912	Ratio : b/a
No. 6598	2.4462 m.	0.0461 m.	2.03 %
„ 6596	1.1761	0.0278	2.36
„ VI	0.3664	0.0092	2.51

Thus the amount of the restitution (depression) of the markedly disturbed localities was at first proportional to that of the original

elevation. After 1913, the recovery process became very slight, and was, as illustrated in fig. 2, nearly of a constant rate for the three bench marks in question. This last fact is found to be approximately true of all the bench marks elevated on the occasion of the eruption of 1910, as explained next.

4. Height change between 1913 and 1919. Table VI gives the height changes between 1913 and 1919 and between 1905 and 1912. It will be observed that the A group bench marks, which had experienced an elevation in 1910, have all been depressed in the course of the 6 years, 1913–1919, to nearly the same amount, namely, from 0.0133 m. to 0.0217 m., with the mean value of 0.0172 m. It thus seems that the Usu-san region elevated by the eruption is, after 1913, settling down as a whole, at the average rate of 0.0172/6 m. =3 mm. per year, irrespective of the extent of the change in 1910. On the other hand, the B group bench marks, which had undergone a depression in the latter year, indicated irregular and very slight changes in the time interval under consideration, giving on the average the depression rate of 0.13 mm. per year.

From the map (fig. 3) illustrating the results stated above, it will be seen that the depression curve of 15 mm. runs on the W. and the S. sides of the Usu-san approximately along the contour lines, the amount of the depression (height restitution) probably being greater at or near the centre of the volcano.

5. Height in 1911 and 1912 compared to that in 1919. To obtain a general idea about the level change subsequent to the eruption, let us take the B.M. No. 7191 as the fixed point, and compare the heights in 1911 and 1912 with those in 1919. The results (fig. 4) indicate a well-marked depression all about the Usu-san, which, in the interval of the 7 or 8 years concerned,

reached the mean group values of 0.0423 m., 0.0269 m., and 0.0175 m., as follows:—

B. M. No. 6596	−0.0422 m.	
6598	−0.0424	Mean, −0.0423 m.
7194	−0.0271	
VI	−0.0267	„ −0.0269 m.
7193	−0.0181	
7195	−0.0176	
7196	−0.0171	
7197	−0.0147	„ −0.0175 m.
7198	−0.0172	
6597	−0.0202	

To the S.E. and the N.W. of the area in question there was a slight height change, resulting in the mean depression of 0.0060 m. and the mean elevation of 0.0025 m.:—

B. M. No. 7196	−0.0082 m.	
7199	−0.0037	Mean, −0.0060 m.
6599	+0.0032	
6600	+0.0043	„ +0.0025 m.
6601	+0.0010	

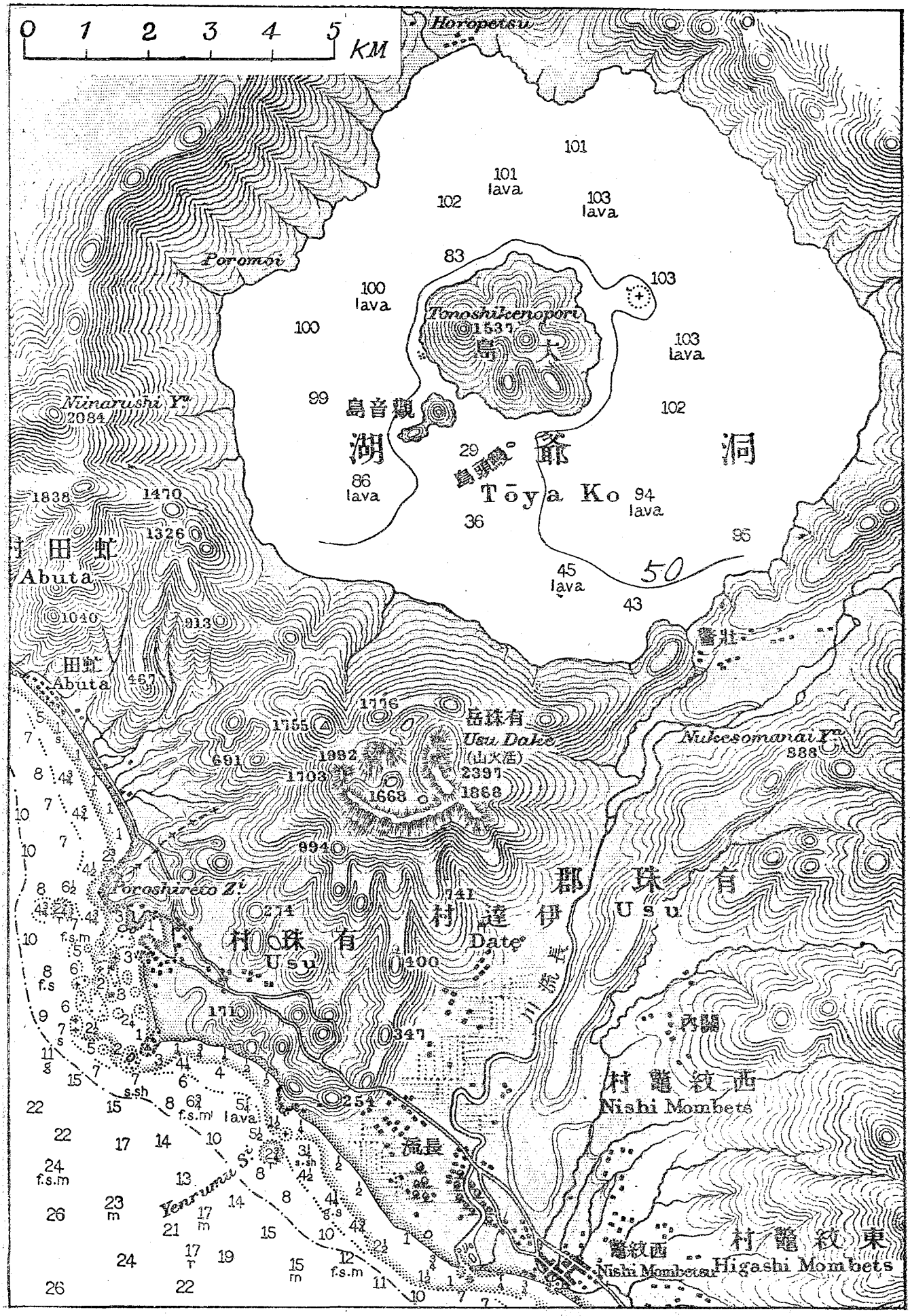
6. Remark on the height variation. Subsequent to the remarkable elevation phenomena which accompanied the Usu-san eruption of 1910, the restitution process has set in, whose maximum effect was indicated at the B.M. No. 6598, the ratio of the total amount of the recovery to the original upheaval being 2.7 : 100. Since 1913, the process of the depression has become much slower, being only 3 mm. per year. Even supposing this change rate to be continued for 100 years, the resultant depression would be some 30 cm., which is far smaller than the elevation in 1910 of the B.M. Nos. 6596 and 6598. Hence the region elevated in the last eruption would not be brought back to its old level before the next volcanic disturbance, likely to occur earlier, but

preserve the elevated condition essentially for ever. The restitution or level depression, which set in since 1911, extended also over the greater portion of the adjacent tract which had suffered a slight depression in 1910. The depression effect of the latter was, as may easily be imagined much smaller than the restitution change of the originally upheaved area.

7. Lake Toya and New Mountain. The lake of Toya, separated by the Usu-san from the Volcano Bay, is an irregular circle or rather a hexagon, about 11 km. in diameter, whose surface is about 85 m. above sea-level. Nearly at the centre of the lake there is situated the island of Nakano-shima (or O-shima), 441 m. in height and about 3 km. in diameter, with the appendage of the small islets of Kwannon-jima off the S.W. and a sunken rock off the N.E. coast. According to the hydrographic chart of the navy, issued in 1904, the maximum depth of the lake found to the N.E. and the E. of the Nakano-shima, was 103 fathoms=188 m. (See fig. 5.) According, however, to the soundings made by Dr. Hidezo Tanakadate in 1917, the water depth at the corresponding portion of the lake nowhere exceeded 180 m.=99 fathoms, while the maximum depth found off the N.W. coast, was 184 m.=101 fathoms. (See fig. 6.) This discrepancy is of the same order of magnitude as the depression and elevation of the bottom of the inner Kagoshima bay produced by the great Sakura-jima eruption of 1914, and may possibly be attributed to the upward volcanic tension which resulted in the formation of the New Mountain, and which might have affected also the deeper part of the lake bottom, as the latter must have been brought down to its present level by the subsidence related to the volcanic action in the immediate neighbourhood and must specially be sensitive to changes in the vertical direction.

Fig 5. Chart of the Lake of Toya (Toya Ko).

Reproduced from the Imperial Navy Hydrographic Chart No. 17, published in 1904, or 6 years before the Usu-san Eruption of 1910.

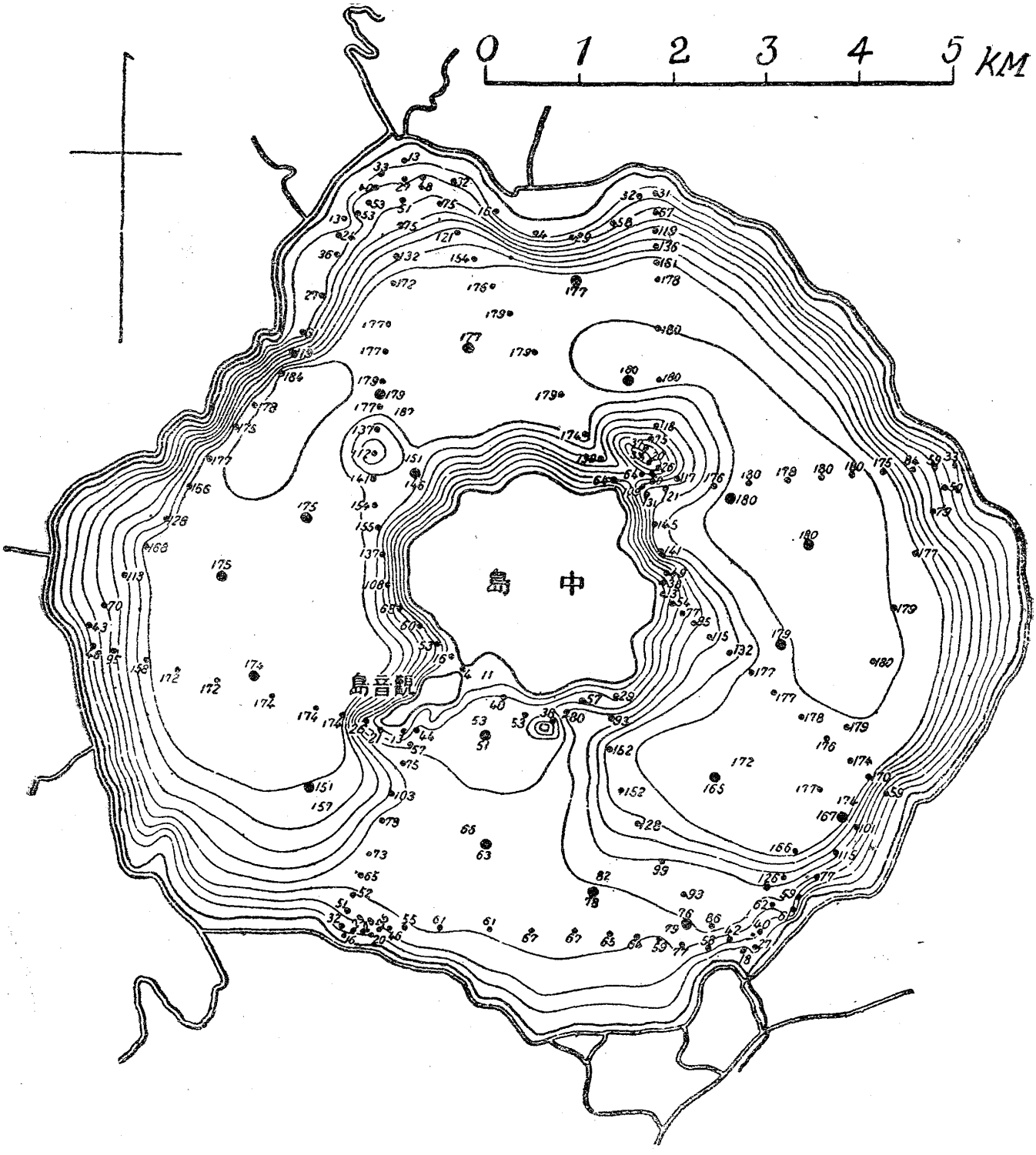


Soundings in fathoms. Height expressed in feet above H.W. Springs of the Volcano Bay.

Fig. 6. Chart of the Lake of Toya.

Compiled by Dr. Hidezo Tanakadate from his soundings made in 1917. Reproduced from the Chigak-Zasshi (Journal of Geographical Society of Tokyo), 1918.

Soundings in metres.
Isobaths are drawn for every 20 m. depth.



The Usu-san Eruption of 1910. (F. Omori, phot.)

Outburst of vapour and mud from the craterlet at the south foot of the West Maru-yama, photographed on July 31st, 1910. (×) Mud Stream. (××) West Maru-yama.

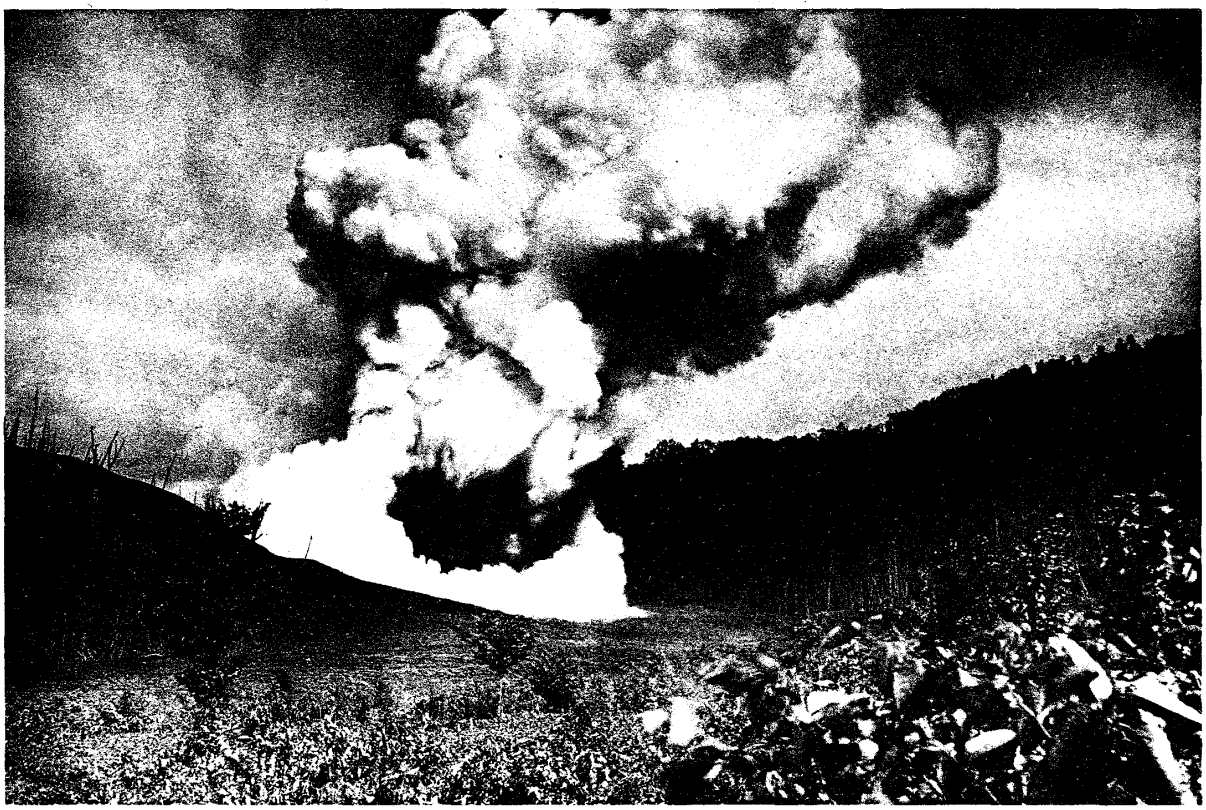


Fig. 7. Moist material spreading out in divergent pointed forms at the base of the smoke column.

Fig. 8. Projection of moist material in a single spear-head like shape. Height of ascent = 100 m.

The Usu-san Eruption of 1910. (F. Omori, phot.)

Fig. 9. Elevation of the West Kohan Lake Coast: a small wooden pier (×) standing entirely out of the water, which had receded several metres from the coast. (Aug. 3rd, 1910.)

Fig. 10. A consequence of the Elevation of the new Mountain: Cottages at Pontokari overthrown on account of the increasing inclination of the ground. The submerged trees show the subsidence of the shore due to the elevation of the northern slope of the New Mountain.
(Nov. 10th, 1910.)

From figs. 5 and 6 it will be seen that, except on the south, the water depth rapidly increased off the coast as well as off the Nakano-shima island, the boundary of the flat bottom of the lake 2 km. in width and about 90 fathoms or 160 m. in depth, being reached at the distance generally of 450 m. to 1 km. from either. On the south, the Nakano-shima is connected to the Usu-san by a submerged plateau or ridge, 2 km. in width and less than 50 fathoms in depth. The presence of this elevated portion surrounded on three sides by a deep depression is a feature verified more or less similarly in the case of the inner Kagoshima bay, where the shallow area surrounding the Anei (1779) islets protrudes northwards from the N.E. coast of the Sakura-jima and separates the deep basin into the western and eastern parts. (See the Bulletin, Vol. VIII, No. 4.)

It is interesting that the New Mountain of 1910 has been raised on the southern prolongation or end of the ridge between the Usu-san and the Nakano-shima, which belongs undoubtedly to the same system of elevation as these volcanoes themselves. The formation of the inner and higher side of the New Mountain by a dislocation along a line in the direction of E.E.S.–W.W.N. seems to indicate that the upheaving volcanic force was manifested along a crack or zone of the secondary nature formed at right angles to the length of the ridge in question. In this connection, it may be noted that the line joining the O-Usu (the greater Usu) and the Ko-Usu (the lesser Usu), mutually distant 850 m., is in the direction of E.E.S. and W.W.N. (See Pl. III, the Bulletin, Vol. V, No. 1.) These two Usu-san domes may, therefore, be regarded as having been formed along a crack, which belongs to the same category as the dislocation of the New Mountain and was formed normal to the volcanic line joining the centres of the Usu-

san and the Toya lake. The newer and greater dome of O-Usu is also, amongst the others, diametrally cleft by a dislocation line running in the direction of N60°W.-S.60°E.

8. Elevation of the West Kohan coast of the lake. In connection with the formation of the New Mountain, the elevation of the West Kohan (or Pontokari) coast of the Toya and the increase of the lake water on the occasion of the Usu-san eruption in 1910, will be here considered in detail. (For a brief general account of the observations relating to the facts in question, the reader is referred to the Bulletin, Vol. V, No. 1.)

The elevation of the ground at West Kohan at the S.S.E. coast of the lake, first noticed on Aug. 6th (1910), extended for the length of about 1 mile and had began on, or more likely earlier than, the date of the first eruption, namely, July 25th. To observe the subsequent rate of the elevation, the height of the lake surface was measured by means of a graduated post erected in the shallow water in front of the West Kohan village school, near the east end of the affected coast and the result was compared with the readings of the level-gauges at the 4 other places situated around the lake, namely, Naka-Toya, Muko-Toya, Takinoue, and Tokotan (Kohan Tokotan). The level observation at the former two of these places was instituted temporally after the commencement of the eruption, while that at the latter two had been commenced some time previously by the Hokkaido Government for the fishery purpose. The measurement at the different places, whose positions are indicated on the maps, figs. 1, 3, and 4, was made by the present author in conjunction with Messrs. Toyokra and Kajinuma, directors of the meteorological observatories of Sapporo and Hakodate respectively, and their assistants, in 1910 and 1911, as follows:—

TABLE VII. Mean Group Values of the Level Gauge Reading at Different Places on the Coast of the Lake of Toya.

Date. (Month, Day.)	Level Gauge Reading at					Difference.	
	(I) Tokotan.	(II) Takinoue.	(III) West Kohan School.	(IV) Naka-Toyo.	(V) Mukc-Toya.	(III) and Mean of (I) and (II).	(II) and (III)
	shaku	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*
1910							
VIII, 6	4.38	3.33	1.91	—	—	1.85	1.42
7	—	—	1.66	—	—	—	—
8	—	3.38	1.51	—	—	—	1.87
„	4.50	—	1.51	—	—	—	—
9	—	3.38	1.47	—	—	—	1.91
10–11	4.45	3.45	1.35	—	—	2.60	2.10
12–15	4.15	3.48	1.25	—	—	2.77	2.23
16–19	4.56	3.48	1.09	—	—	2.93	2.39
20–24	4.46	3.40	0.91	—	—	2.92	2.49
25–31	4.40	3.40	0.85	—	2.05	3.05	2.55
IX, 1–7	4.33	3.31	0.81	—	2.02	3.01	2.50
8–14	4.20	3.21	0.77	0.37	1.95	2.94	2.44
15–20	4.10	3.13	0.71	0.31	1.85	2.91	2.42
21–29	4.03	—	—	0.17	—	—	—
XI, 8–11	3.28	2.13	0.10	—	—	2.61	2.03
1911							
IV, 14–28	—	1.97	− 0.11	—	—	—	2.08
XI, 13–15	3.10	2.10	− 0.03	—	—	2.69	2.13

Tokotan (S.W. coast of the lake): Aug. 3rd to Sept. 24th, and Nov. 8th and 9th, 1910; 13th–15th, Nov., 1911.

Takinoue (S.E. coast of the lake): Aug. 3rd to Sept. 19th, and 10th and 11th, Nov., 1910; 14th-28th, April, and 13th-15th, Nov., 1911.

West Kohan School (S.S.E. coast of the lake): Aug. 3rd to Sept.

22nd, and Nov. 10th, 1910; 14th to 28th, April, and 13th-15th, Nov., 1911.

Naka-Toya (N.E. coast of the lake): 9th to 29th, Sept. 1910.

Muko-Toya (N.W. ,, ,,): Aug. 30th to Sept. 20th, 1910.

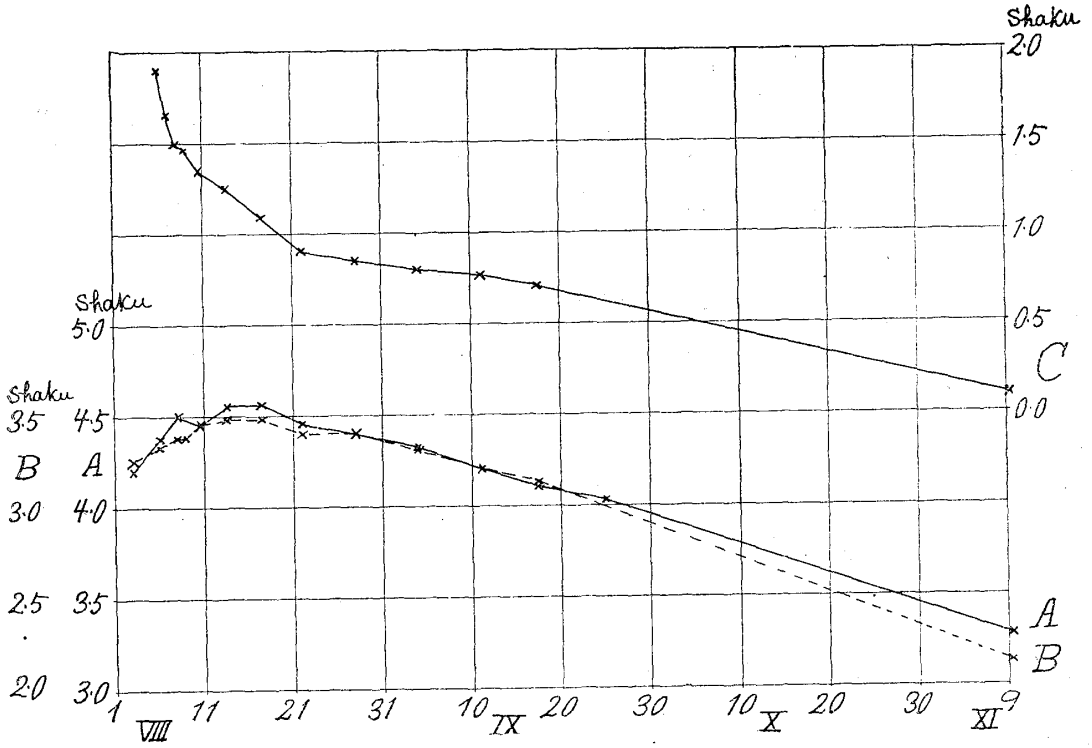


Fig. 11. Height Variation of the Surface of the Lake of Toya at different points of the Coast: Level Gauge Readings at the West Kohan School, Tokotan and Takinoue, Aug. 3rd to Nov. 11th, 1910.

A.....Tokotan. B.....Takinoue. C.....W. Kohan School.

The level-gauge readings at the different places refer to the respective arbitrary zeros.

1 *shaku* = $\frac{1}{3}$ × metre = 0.994 foot.

The results of the observations are contained in Table X, the readings of the lake surface height at the 5 coast stations being referred not to one common datum plane, but to the arbitrary zeros of the respective level gauge posts. As will be seen from Table VII, which is based on Table X and gives the mean values deduced by conveniently grouping the successive observations, the lake water at Tokotan and Takinoue was raised about 0.2 *shaku**

* 1 *shaku* = 0.994 foot = $\frac{1}{3.3}$ × 1 metre.

in the course of the first 20 days of Aug. (1910) and was thereafter gradually lowered, the amount of decrease reaching 1.3 *shaku* on the 10th of Nov. next. On the other hand, at the West Kohan school the lake level was continually lowered since the commencement, the level-gauge indicating the decrease of 1.25 *shaku* in the interval of Aug. to Nov., 1910. Further, a comparison of the height readings at Naka-Toya with those at Tokotan and Takinoue indicates that the increase and decrease of the water level was nearly equal at these 4 places, which consequently must have sufferred no considerable height variation, or, if any, simultaneously and similarly. (See Table VIII.) As illustrated in fig. 11, the height variation of the lake level was almost exactly identical at Tokotan and Takinoue, but was much dissimilar between these two places and the west Kohan school.

TABLE VIII. Comparison of Lake Level Variation at Tokotan, Takinoue, Naka-Toya, and Muko-Toya.

Time Epoch. (1910)	Place of Observation.	Lake Level Variation.
		shaku
1st–7th.....15th–20th, Sept.	Takinoue.....0.18	Decrease.
	Mukc-Toya.....0.17	„
9th–14th.....21st–29th, „	Tokotan.....0.17	„
	Naka-Toya.....0.20	„
9th & 10th.....19 & 20th, „	Naka-Toya.....0.12	„
	Mukc-Toya.....0.16	„
8th–10th.....16th & 17th, Aug.	Tokotan.....0.09	Increase.
	Takinoue.....0.10	„
16th–19th, August. ..... 8th–11th, November.	Tokotan.....1.28	Decrease.
	Takinoue.....1.35	„

In Table XI, the height of the lake surface at Tokotan, Takinoue, and the West Kohan school, are referred to the readings of the graduated level-gauge posts at the respective places on Sept.

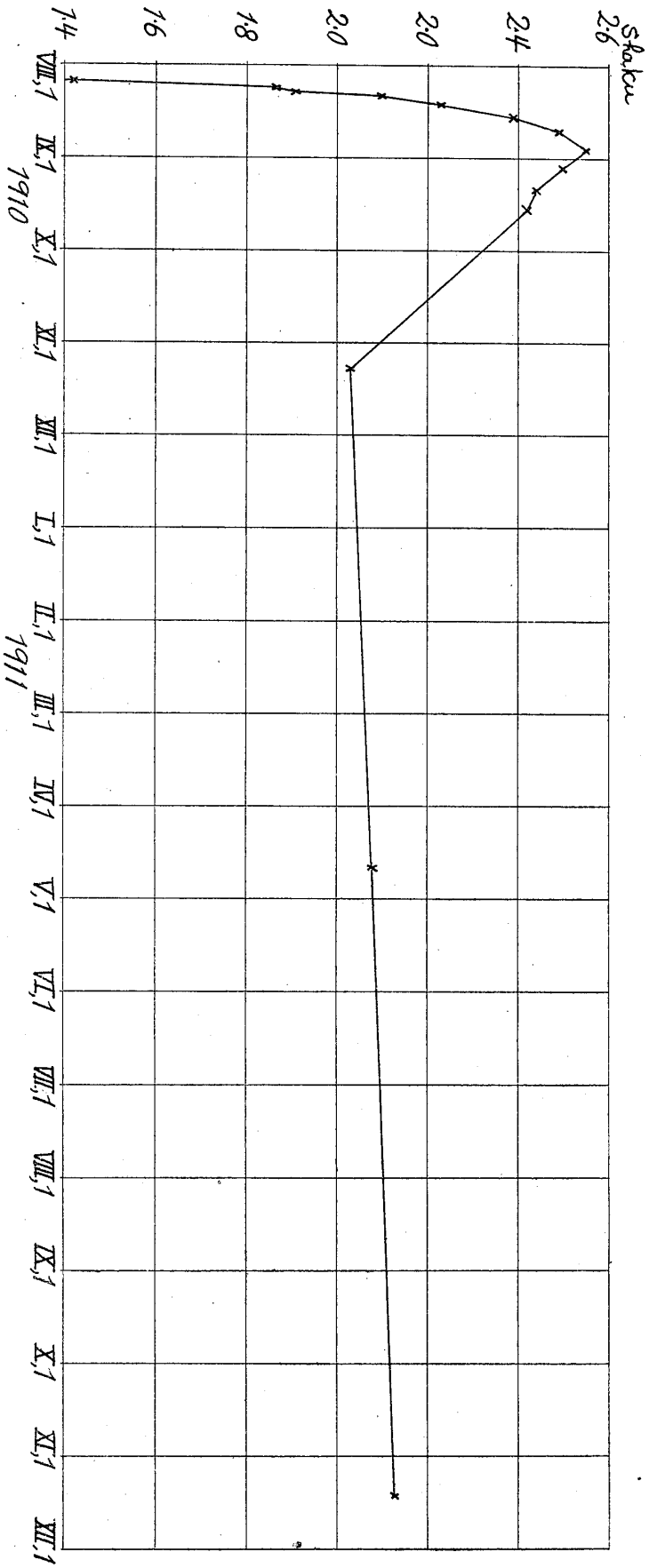


Fig. 12. Elevation of the West Kohan Coast:

Reading at the West Kohan School referred to that at Takinone, Aug. 3rd, 1910, to Nov. 15th, 1911.

1 *shaku* = $\frac{1}{3}$ × metre = 0.994 foot.

18th and 19th, 1910, as about that time the rate of the height variation became slight. The difference between the height readings at the West Kohan school and the mean of the corresponding values at Tokotan and Takinoue, which may be taken as indicating the real amount of the elevation of the ground at the former place, is, in the last column of Table XI, referred to Aug. 6th as the starting epoch.* Again, in the last column of Table X, is given the difference between the corresponding height readings at Takinoue and West Kohan school. The course of the height variation represented by this latter difference is illustrated in fig. 12. The mean elevation reached the maximum some 33 days after the first eruption, namely, on about Aug. 27th; the amount of the rise of the ground between the latter date and the 6th of the same month being 1.13 *shaku*=34.2 cm., with the average rate of nearly 1 cm. per day. Of course the elevation was at first much quicker, there being a rise of 0.68 *shaku*=20.6 cm. in the course of the $4\frac{1}{2}$ days between the 6th and the 10th-11th of Aug. (1910), with the rate of 4.6 cm. per day. On the 6th, when the fact of the vertical change of the ground was first brought into notice, the elevation had already reached 1 m., giving for the 12 days since the 25th of July, the day of commencement of the eruption, the average rate of about 8 cm. per day.

The restitution of the elevated coast at the West Kohan school set in after about Aug. 27th and continued on regularly, the amount of the total depression reached on Nov. 8th-11th, in the course of the 75 days, being 0.52 *shaku*=15.8 cm., with the average of 0.2 cm. per day.

Thereafter the coast in question ceased to exhibit prominent

* The elevation of the ground at the West Kohan school thus deduced, has, on p. 26, the Bulletin, Vol. V, No. 3, been converted into cm.

Table IX. Relative Level-Gauge Readings on 11th-19th, Aug. 1910.

Date (VIII, 1910.) / Place of Observation.	11	12	13	14	15	16	17	18	19
	shaku	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*
W. Kohan School.	0.00	0.05	0.10	0 10	0.14	0.21	0.20	0.30	0.35
60 feet to the west.	0.00	0.06	0.16	0.24	0.45	0.62	0.74	0.91	1.02

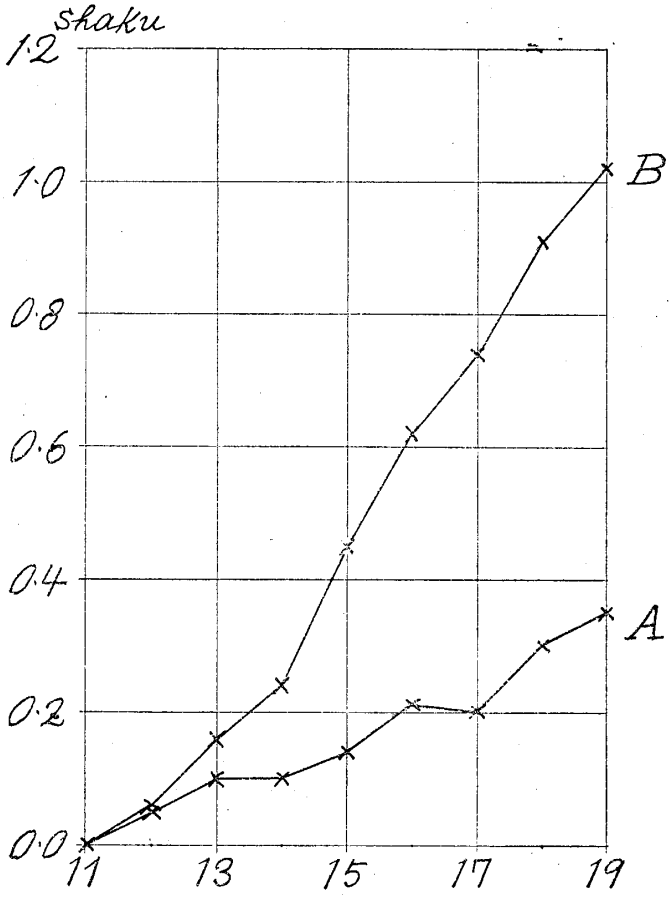


Fig. 13. Elevation of the West Kohan Coast: Change Amount at Neighbouring Points.

Level-gauge reading difference, Aug. 11th-19th, 1910:
(A), In front of the West Kohan School;
(B), At 60 feet to the West of A.

1 *shaku* = $\frac{1}{3}$ × metre = 0.994 foot.

changes, and was found, in April and November of the next year, 1911, to have nearly the same height as in Nov. 1910. The rate of the height decrease ought naturally to be less than that of the height increase, as the extent of the restitution depression was limited to only one-ninth of the elevation.

The amount of the elevation was not uniform along the length of the affected West Kohan coast. Thus, the height readings taken of a graduated level-gauge erected 60 feet to the west of that in front of the West Kohan school indicated in Aug., 11th to 19th, 1910, an elevation about 2.6 times greater than in the case of the latter, as shown in Table IX and fig. 13.

9. Eruption and lake water. The water in the lake of Toya began to become unusually abundant from about the time of the Usu-san eruption in the latter part of July (1910). Consequently the flow in the Sobets river, the only outlet of the lake, was so much increased that in the town of Sobets, where the stream is narrow and about 50 feet in width, the water rose 2 feet higher than in ordinary times, this being an event quite unprecedented. Again, at the Tokotan district, a few houses on the lake shore were very nearly flooded; while the beach of the Kwannon-jima islet in the Toya, ordinarily 10 feet in width, was, at the time of my visit in the begining of Aug. (1910), was entirely submerged, some of the drooping tree branches being also immersed in water. These facts seem to indicate that the lake water increase of about 1 foot at the time of the eruption was rather the consequence of the latter, and not due simply to the annual height variation of the lake surface. As the level gauges at Tokotan and Takinoue showed no marked fluctuations in the height of the surface till the latter part of Aug., the water in the Toya lake and the flow in the Sobets river is to be assumed to have sufferred no great decrease

for about 1 month after the commencement of the eruption. At the time of my second visit, on Nov. 10th (1910), the water height at Sobets as well as at Tokotan and Takinoue was found brought back practically to the ordinary condition.

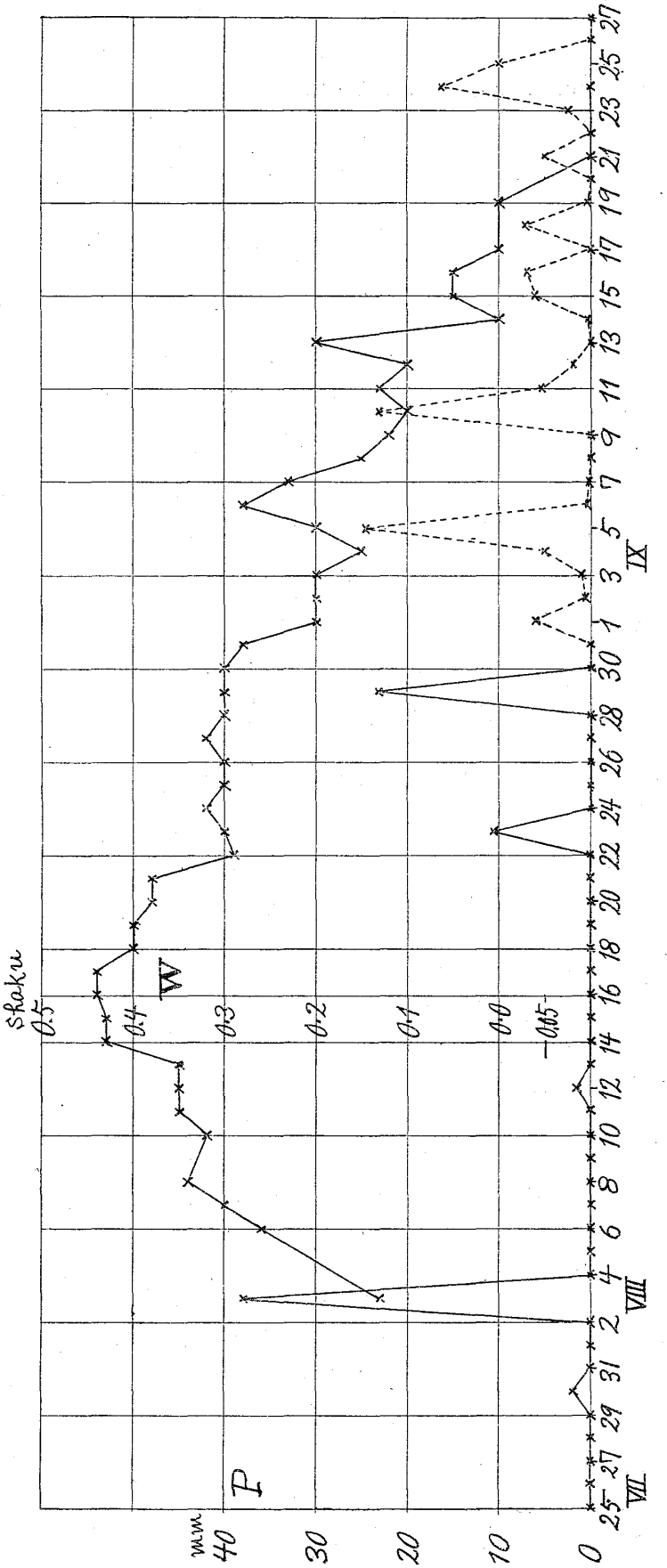
According to Tables X and XI, the lake surface was elevated at Tokotan and Takinoue 0.38 *shaku* (=11.5 cm.) and 0.25 *shaku* (=7.6 cm.) respectively, in the course of the 11 to 13 days after Aug. 3rd (1910), the maximum height being reached on Aug. 14th to 16th. Thereafter the lake surface continued to be lowered, the depression amounting in Nov. (1910) to 1.5 *shaku*= 45.5 cm.

The full meaning of this marked water decrease in November (1910), which is to be regarded as quite special to the occasion under consideration, will be realized by referring to the annual variation of the surface height of the Shikots lake in the Tarumai volcanic district. According to the Shikots level-gauge observations made during the 10 years before the completion of the water-power dam, namely, Jan. 1900 to April 1910, the mean monthly water level in August was 0.147 *shaku* (=4.5 cm.) *lower* than in November; while according to similar observations during the next 10 years, July 1910 to Dec. 1919, after the completion of the dam, the mean level in August was 0.422 *shaku* (=12.8 cm.) *lower* than in November. Again, in the case of the shallow O-numa lake at the S. foot of the Komaga-take volcano, on the opposite side of the Volcano Bay, the mean monthly height of the water surface deduced from the observations in the 6 years, 1913 to 1919, was 1.03 *shaku* (=31.2 cm.) *lower* in August than in November. The occurrence of the maximum level of the Toya lake in Aug. 1910 was thus different from the usual habit of the other volcanic lakes in the S.W. part of Hokkaido.

Fig. 14. Variation of the Height of the Lake Surface and the Amount of Precipitation, in July and August, 1910.

W.....Lake level, meaned from the observations at Tokotan and Takinoue.
(1 *shaku*=0.994 foot.)

P.....Amount of precipitation : full line for Abuta, and dotted line for Sobets.



10. Precipitation and lake water. In Table XII is given the daily amount of precipitation observed in July-October, 1910, at the village office of Abuta and the elementary school of Sobets; these two places being to the S.W. and to the S.E. of the Toya, respectively at distances of 4 and 1 km. from the nearest lake coast. The precipitation was small during July and Aug., the total amounts for these two months being at Abuta 14.6 mm. and 73.2 mm. respectively. The precipitations in September and October next were great, being at Sobets respectively 122.5 mm. and 35.7 mm. Fig. 14 graphically illustrates the course of the variation of the height of the lake surface and of the amount of the precipitation in Aug. and Sept. (1910). It is difficult to conceive the precipitation on Aug. 3rd as the agency, which caused the marked elevation of the water level at the middle of Aug. In connection with the question of the precipitation, the following account of the daily weather and the condition of the lake level at Naka-Toya, on July 22nd-30th (1910), is of a special interest:—

22nd. Fair; warm in the evening.

23rd. Cloudy.

24th. Fair.

25th. Fair: strong S.E. wind.

26th. Cloudy.

27th. Fair; explosive sounds heard between 1 and 4 a.m. There were rumours of an overflooding of the lake water, and some of the people fled to the hilly parts. Level-gauge erected at the coast.

28th. Rainy. At 11 a.m., strong rain and thunders. At 6 p.m., the level gauge indicated 0.3 *shaku* (=9 cm.) rise of water surface.

29th. Rainy. At 6 a.m. the level gauge reading was 0.3 *shaku* higher than on the previous day.

30th. Rainy. There was a further water increase of 0.3 *shaku*.

Thus, at Naka-Toya, there was an increase of the aggregate amount of about 0.9 *shaku*=27.3 cm. during the three days of July 28th-30th. This rise of the water surface might be related to the rainy condition of the days in question, but certainly not to a significant degree, as may be inferred from the following instances. According to Tables XII and X, there were at Sobets on Sept. 5th and 10th the precipitation of the amounts of 24.6 mm. and 23.2 mm. respectively. Yet none of the level-gauges at Tokotan, Takinoue, Naka-Toya, and Muko-Toya indicated any special water increase on those days or on the following days.

11. Cause of increase of lake water. The increase of the water of the lake of Toya considered in §9 might be due to the following three circumstances:–(i), the precipitation; (ii), flowing in of the volcanic mud; and (iii), the elevation of the lake bottom. The amount of the precipitation (i) in the vicinity of the lake at the time of the eruption seems, as mentioned in §10, not sufficient to produce the water increase in question. With respect to (ii), there were poured very often mud streams from some of the craterlets of the 1910 eruption into the Toya, the entire lake water being thereby turned turbid and light-greenish in colour. The total amount of the mud thus carried into the lake was, however, comparatively small. Even the volume of the volcanic material carried down by the mud stream from the craterlet at the S. base of the W. Maru-yama, which was the greatest of the kind in the 1910 eruption, was probably not much above $300 \times 300 \times 3$ m. = 1/3000 c. km. The contribution by the other smaller mud streams were much more insignificant. As the area of the Toya lake is about 73 sq. km., the inflow of the muds taken together would

have raised at the most the water level only by 1 cm. Lastly, with respect to the change of the lake bottom (iii), let us imagine an area of 10 sq. km. of the latter was elevated 2 m. The lake surface would then be raised about 30 cm. or 1 *shaku*. If the elevation of the same area be 3 m., the water surface would be raised 45 cm. $= 1\frac{1}{2}$ *shaku*. Thus the elevation of the lake bottom of the magnitude here assumed can fully account for the actual change of the height of the water surface. This hypothesis is moreover in accordance with the probable reduction of the depth of the water revealed by the soundings (§7).

12. Temperature of lake water. For the sake of reference I give in Table XIII the temperature of the Toya lake in Aug., Sept., and Nov., 1910, at Tokotan, Takinoue, and West Kohan; the measurement having been made in each case at the distance of about 2 metres from the coast, and at the depth of about 30 cm. below the water surface. The mean results were as follows: —

Time Interval. (1910)	Lake Water Temperature.			(IV) Air Temperature.	Difference, (III)-(IV)
	(I) Maximum.	(II) Minimum.	(III) Mean.		
(1) VIII, 2nd–14th.	21.7° C.	18.1° C.	20.0° C.	21.9° C.	– 1.9°
(2) „ 15th–23rd.	22.6	21.2	21.7	23.0	– 1.2
(3) „ 24th–31st.	24.0	22.4	23.5	22.2	1.2
(4) IX, 1st–10th.	22.6	21.0	21.9	19.8	2.0
(5) XI, 8th–11th.	13.2	11.7	12.2	7.9	4.4

Thus the water temperature was highest in the (3) epoch, Aug. 24th-31st, the corresponding mean value being somewhat higher than those of the air temperature in the different epochs. (See fig. 15.) It is hereby to be remarked that the water tempe-

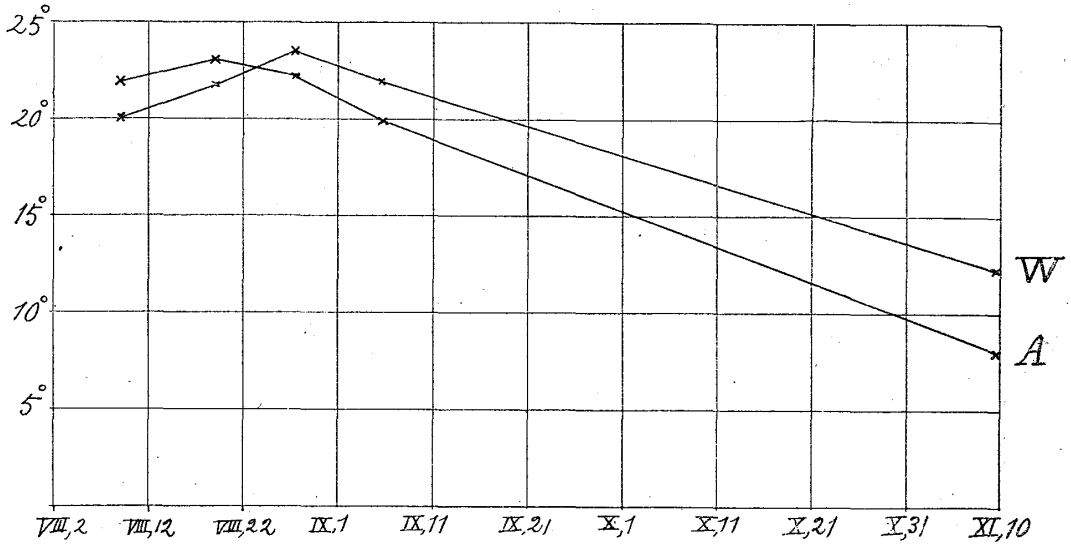


Fig. 15. Temperature of the Lake Water compared to that of Air, Aug. o Nov. 1910.
W.....Lake water temperature. A.....Air temperature.

rature was thus maximum in the latter part of the month of August (1910), when the elevation of the West Kohan coast was at the maximum limit, and when the process of formation of the New Mountain was most active. These circumstances seem to indicate that cracks were formed at the time of the eruption also at the bottom of the Toya, thereby introducing some hot waters from below and increasing to a certain extent the temperature of the lake water. The existence of the submerged hot springs is probable, as the lake of Toya does not freeze in winter. The hot spring, at the lake coast to the north of the West Maru-yama, brought into existence after the eruption and at present 42°C. in temperature apparently belongs to the category here supposed.

13. The Volcano Bay. The Volcano Bay, or Uchiura-wan, which is nearly circular and has the diameter of about 50 km., owes probably its origin to a volcanic depression. It is continued at the S.E. to the Pacific ocean by an opening 27 km. wide, at whose N.E. and S.W. ends are placed the port of Muroran and the volcanic mass of the Komaga-take respectively. In spite of

the large extension the bay is shallow and has the maximum depth of only 59 fathoms=107 m. As will be seen from fig. 16, the contour lines of the bottom, which is on the whole flat, are not arranged symmetrically with respect to the centre, the deepest area being situated at the western part of the bay. This depth eccentricity may be assumed to be the result of a slight elevation of the eastern part of the bay along the straight line joining the Usu-san and the Nakano-shima in the Toya lake, on the north, with the Komaga-take volcano on the south.

14. Relation of Volcano Bay to Toya and Shikots lakes. The lake of Shikots, situated between the two volcanoes of the Tarumai-dake and the Eniwa-dake, about 76 sq. km. in area, owes its origin also to a volcanic depression and is flat-bottomed and deep, with the maximum water depth of 358 m. A fact of special interest with respect to the Volcano Bay is the approximate identity of the bottom depth with those of the two volcanic lakes of Toya and Shikots, as follows: —

Bottom of the Volcano Bay.....107 m. below sea level.
,, Toya lake .....103 m. ,,
,, Shikots lake.....110 m. ,,

The depth of about 110 m. below the sea level seems to indicate the limit of the volcanic depression in the S. W. part of Hokkaido. (See the Bulletin, Vol. VIII, No. 4.)

Fig. 16. Isobathymetric Chart of the Volcano Bay. PL. XVII.

(Based on the Imperial Navy Hydrographic Chart No. 17. published in 1904.) Depth in fathoms.

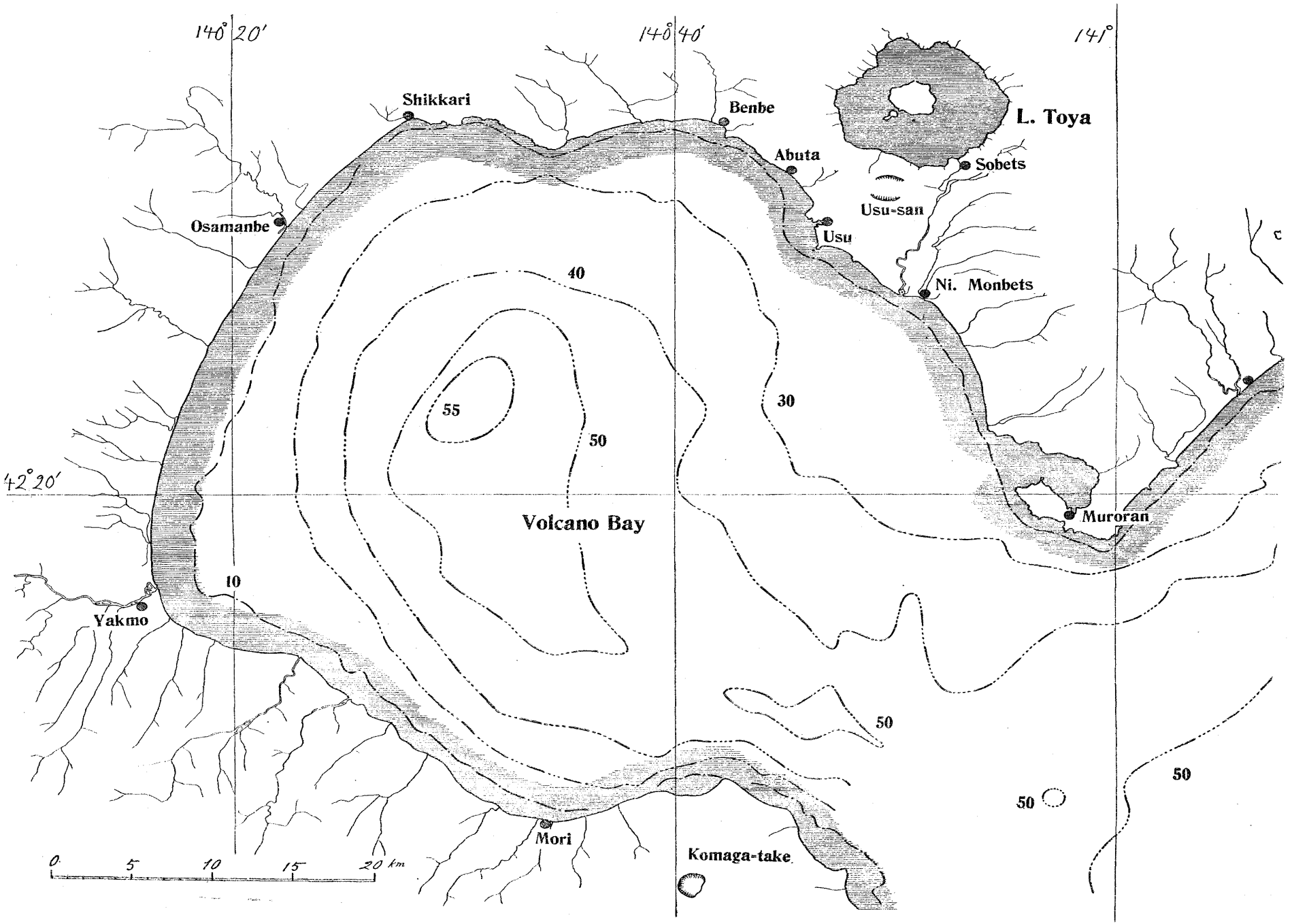


TABLE X. Height of the Water Surface observed at Different Places on the Coast of the Lake of Toya, Aug. 3rd, 1910, to Nov. 15th, 1911.

(The reading at each place is referred to the arbitrary zero of the level gauge.)

Date.	Tokotan.	Takinoue.	West Kohan School.	Naka-Toya. (6 A.M.)	Muko-Toya. (6. A.M.)	Weather.	Precipitation.
VIII, 1910.	*shaku.*	*shaku.*	*shaku.*				mm.
3	4.20 (10¼ A.M.)	3.25 (4⅔ A.M.)					
6	4.38	3.33	1.91				
7	—	—	1.66				
8	4.50 (11⅝ A.M.)	3.38 (8⅔ A.M.) 3.38 (6⅔ P.M.)	1.51				
9	—	3.38 (11⅙ A.M.)	1.47				
Mean.	**4.35**	**3.35**					
10	4.45 (10½ A.M.)	3.39 (7¾ A.M.)	1.35 (2 P.M.)				
11	—	3.45	1.35			Rainy.	
Mean.	4.45	**3.42**	**1.35**				
12	—	3.45	1.30			Rainy.	
13	—	3.45	1.25			„	
14	4.55 (4 P.M.)	3.50	1.25			„	
15	4.55 (1 P.M.)	3.50	1.21			Cloudy.	
Mean.	**4.55**	**3.48**	**1.25**				
16	4.58 (2 P.M.)	3.50	1.14			Clear.	
17	4.57 (10 A.M.)	3.50	1.15			„	
18	4.55 (11 A.M.)	3.45	1.05			„	
19	4.55 (1 P.M.)	3.45	1.00			„	
Mean.	**4.56**	**3.48**	**1.09**				
20	4.55	3.40	0.95			Cloudy.	
21	4.55	3.40	0.90			„	
22	4.40	3.38	0.88			„	
23	4.40	3.40	0.92			Rainy.	
24	4.40	3.44	0.90			Clear.	
Mean.	**4.46**	**3.40**	**0.91**				
25	4.40	3.40	0.86			Cloudy.	
26	4.40	3.40	0.84			„	
27	4.40 (9 A.M.)	3.43	0.84			Fair.	
28	4.40	3.40	0.84			„	
29	4.40 (11 A.M.)	3.40	0.85			Rainy.	8.5

TABLE X. (*Cont.*)

Date.	Tokotan.	Takinoue.	West Kohan School.	Naka-Toya. (6. A.M.)	Muke-Toya. (6. A.M.)	Weather.	Precipitation.
VIII, 1910.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*		mm.
30	4.40 (9 A.M.)	3.39	0.87		2.05	Cloudy.	0.0
31	4.40 (9 A.M.)	3.35	0.86		2.05	„	0.9
Mean.	**4.40**	**3.40**	**0.85**		**2.05**		**3.1**
IX, 1910.							
1	—	3.30	0.80		2.05	Rainy.	6.0
2							
3	—	3.30	0.80		2.03	Rainy.	1.0
4	—	3.25	0.80		2.00	„	4.9
5	—	3.30	0.80		1.95	„	24.6
6	4.35 (11 A.M.)	3.40	0.86		2.03	„	0.2
7	4.30 (11 A.M.)	3.35	0.81		2.02	„	0.1
Mean.	**4.33**	**3.31**	**0.81**		**2.02**		**5.3**
8	—	3.25	0.78	—	1.97	Cloudy.	—
9	4.20 (4 P.M.)	3.23	0.75	0.40	1.95	„	—
10	4.20	3.20	0.75	0.40	1.93	Rainy.	23.2
11	4.20	3.25	0.77	0.38	1.94	„	5.3
12	4.20	—	—	0.35	1.94	„	1.8
13	—	3.30	0.80	0.35	1.95	—	—
14	—	3.10	0.75	0.35	1.94	Fair.	0.3
Mean.	**4.20**	**3.21**	**0.77**	**0.37**	**1.95**	—	**4.4**
15	—	3.15	0.75	0.32	1.91	Rainy.	6.1
16	—	3.15	0.70	0.32	1.90	Clear.	6.9
17	4.10	—	0.70	0.32	1.85	„	—
18	—	—	0.70	0.30	1.85	Fair.	7.3
19	4.10	3.10	-	0.30	1.80	Rainy.	0.3
20	—	—	—	0.27	1.77	Fair.	—
Mean.	**4.10**	**3.13**	**0.71**	**0.31**	**1.85**		**3.4**
21	4.00	—	—	0.20		Fair.	5.0
22	—	—	0.62	0.20		Rainy.	0.0
23	—	—	—	0.20			2.4
24	4.00	—	—	0.20			16.3
25	—	—	—	0.15			10.0
26	—	—	—	0.15			0.0
27	—	—	—	0,15			0.0
28	—	—	—	0.13			0.0

TABLE X. (*Cont.*)

Date.	Tokotan.	Takinoue.	West-Kohan School.	Naka-Toya. (6. A.M.)	Muko-Toya. (6. A.M.)	Weather.	Precipitation.
IX, 1910.	*shaku.*	*shaku.*	*shaku.*	*shaku.*			mm.
29	—	—	—	0.13			0.0
Mean.	**4.03**	—	—	**0.17**			**3.7**
XI, 1910.							
8	3.25 ($9\frac{5}{6}$ A.M.)	—	—				
9	3.30	—	—				
10	—	2.10 ($9\frac{1}{2}$ A.M.)	0.10 ($4\frac{1}{2}$ P.M.)				
11	—	2.15 (2 P.M.)	—				
Mean.	**3.28**	**2.13**	0,10				
IX, 1911.							
14		—	—			Fair.	
15	*	1.68 (8 A.M.)	—			,,	
16		—	—			,,	
17		1.78	−0.40 (11 A.M.)			Slightly rainy. Strongly windy.	
18			−0.10			Stormy.	
19		2.03 (6 P.M.)	−0.10				
20		1.96 (7 A.M.)	−0.15 ($7\frac{1}{2}$ A.M.) −0.10 (4. P.M.)				
21		—	−0.02 ($7\frac{2}{3}$ A.M.)				
22		—	−0.15 ($7\frac{2}{3}$ A.M.)				
23		—	−0.10 (9 A.M.)				
24		2.03 (6 P.M.)	−0.20 (8 A.M.)				
25		—	−0.02 (9 A.M.)				
26		—	−0.05 9 A.M.)				
27		—	−0.02 (3 P.M.)				
28		2.04 (Noon.)	0.00 ($7\frac{1}{2}$ A.M.)				
Mean.		**1.97** (*excepted.)	**−0.108**				
XI, 1911.							
13	3.10 ($11\frac{1}{4}$ A.M.)	—	0.00 ($4\frac{1}{3}$ P.M.)			Rainy, windy.	
14	—	2.10 ($9\frac{1}{2}$ A.M.)	−0.05 ($10\frac{1}{4}$ A.M.)			Snowy, windy.	
15	—	2.10 (8.25 A.M.)	—			Clear, calm.	
Mean.	**3.10**	**2.10**	**−0.025**				

TABLE XI. Height of the Lake Surface at Tokotan, Takinoue, and West Kohan School, Aug. 3rd, 1910 to Nov. 15th, 1911.

(The height reading at each place in referred to that on Sept. 18th-19th as zero.)

Date.	Tokotan.	Takinoue.	Mean of Tokotan and Takinoue. I	West Kohan School. II	Difference I−II= III	shaku III+0.95 =III′
1910.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
VIII, 3	0.10	0.15	0.13	—	—	—
4	0.40	0.28	0.34	—	—	—
5	—	—	—	—	—	—
6	0.28	0.23	0.26	1.21	− 0.95	0 00
7 0½ P.M.	—	—	0.30	1.06	− 0.76	0.19
7 6 P.M.	—	—	0.31	0.86	− 0.55	0.40
8 8 A.M.	—	0.28	0.28	0.81	− 0.53	0.42
8 Noon.	0.40	—	0.40	0.81	− 0.41	0.54
9 (Noon).	—	0.28	0.28	0.77	− 0.49	0.46
10	0.35	0.29	0.32	0.65	− 0.33	0.62
11	—	0.35	0.35	0.65	− 0.30	0.65
12	—	0.35	0.35	0.60	− 0.25	0.70
13	—	0.35	0.35	0.55	− 0.20	0.75
14	0.45	0.40	0.43	0.55	− 0.12	0.83
15	0.45	0.40	0.43	0.51	− 0.08	0.87
16	0.48	0.40	0.44	0.44	0.00	0.95
17	0.47	0.40	0.44	0.45	− 0.01	0.94
18	0.45	0.35	0.40	0.35	+ 0.05	1.00
19	0.45	0.35	0.40	0.30	+ 0.10	1.05
20	0.45	0.30	0.38	0.25	+ 0.13	1.08
21	0.45	0.30	0.38	0.20	+ 0.18	1.13
22	0.30	0.28	0.29	0.18	+ 0.11	1.06
23	0.30	0.30	0.30	0.22	+ 0.08	1.03
24	0.30	0.34	0.32	0.20	+ 0.12	1.07
25	0.30	0.30	0.30	0.16	+ 0.14	1.09
26	0.30	0.30	0.30	0.14	+ 0.16	1.11
27	0.30	0.33	0.32	0.14	+ 0.18	1.13
28	0.30	0.30	0.30	0.14	+ 0.16	1.11
29	0.30	0.30	0.30	0.15	+ 0.15	1.10
30	0.30	0.29	0.30	0.17	+ 0.13	1.08
31	0.30	0.25	0.28	0.16	+ 0.12	1.07

TABLE XI. (*Cont.*)

Date.	Tokotan.	Takinoue.	Mean of Tokotan and Takinoue. I	West Kohan School. II	Difference I − II = III	shaku III + 0.95 = III′
1910.	*sha'u.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
IX, 1	—	0.20	0.20	0.10	+ 0.10	1.05
2	—	0.20	0.20	0.13	+ 0.07	1.02
3	—	0.20	0.20	0.10	+ 0.10	1.05
4	—	0.15	0.15	0.10	+ 0.05	1.00
5	—	0.20	0.20	0.10	+ 0.10	1.05
6	0.25	0.30	0.28	0.16	+ 0.12	1.07
7	0.20	0.25	0.23	0.11	+ 0.12	1.07
8	—	0.15	0.15	0.08	+ 0.07	1.02
9	0.10	0.13	0.12	0.05	+ 0.07	1.02
10	0.10	0.10	0.10	0.05	+ 0.05	1.00
11	0.10	0.15	0.13	0.07	+ 0.06	1.01
12	0.10	—	0.10	—	—	—
13	—	0.20	0.20	0.10	+ 0.10	1.05
14	—	0.00	0.00	0.05	− 0.05	0.90
15	—	0.05	0.05	0.05	0.00	0.95
16	—	0.05	0.05	0.00	+ 0.05	1.00
17	0.00	—	0.00	0.00	0.00	0.95
18	—	—	—	0.00	0.00	0.95
19	0.00	0.00	0.00	—	—	—
20	—	—	—	—	—	—
21	− 0.10	—	− 0.10	—	—	—
22	—	—	—	− 0.08	—	—
23	—	—	—	—	—	—
24	− 0.10	—	− 0.10	—	—	—
XI, 8	− 0.85	—	− 0.85	—	—	—
9	− 0.80	—	− 0.80	—	—	—
10	—	− 1.00	− 1.00	− 0.60	− 0.40	0.55
11	—	− 0.95	− 0.95	—	—	—
1911.						
IV, 17—28	—	− 1.03	− 1.03	− 0.81	− 0.22	0.73
XI, 13—15	− 1.00	− 1.00	− 1.00	− 0.73	− 0.27	0.68

Table XII. Precipitation at Abuta and Sobets, May to October, 1910.

Day. (1910)	Abuta.		Sobets.		
	July.	August.	August.	September.	October.
	mm.	mm.	mm.	mm.	mm.
1	—	—		6.0	0.0
2	—	—		0.4	0.0
3	—	38.0		1.0	0.1
4	—	—		4.9	0.0
5	—	—		24.6	0.0
6	—	—		0.2	0.0
7	4.0	—		0.1	0.0
8	4.6	0.0		—	5.8
9	1.0	0.0		—	0.3
10	1.5	—		23.2	0.0
11	0.5	—		5.3	3.8
12	—	1.5		1.8	0.0
13	—	—		—	0.0
14	—	—		0.3	0.0
15	—	—		6.1	0.0
16	—	—		6.9	0.0
17	—	—		—	2.6
18	—	—		7.3	41.9
19	—	—		0.3	4.3
20	1.0	—		—	—
21	—	—		5.0	17.5
22	—	—		0.0	5.7
23	—	10.5		2.4	—
24	—	—		16.3	3.7
25	—	—		10.0	0.0
26	—	—		0.0	0.0
27	—	—		0.0	0.0
28	—	—		0.0	0.0
29	—	23.2	8.5	0.0	0.0
30	2.0	—	0.0	0.0	0.0
31	—	—	0.9		0.0
Sum.	**14.6**	**73.2**	—	**122.5**	**85.7**

TABLE XIII. Surface Water Temperature of the Lake of Toya, Aug. 2nd–Nov. 11th, 1910.

Place of observation.	Month.	Day.	Time.	Weather.	Wind.		Temperature.		
					Direction.	Intensity.	Air.	Water.	Difference.
							C.	C.	C.
Tokotan.	VIII	2	5. P.M.	Cloudy.	S.E.	Light.	—	20.5	—
,,		3	10. A.M.	,,	S.E.	,,	19.4	20.6	1.2
Takinoue.		3	5.10 P.M.	,,	—	—	20.2	20.8	0.6
West Kohan.		6	5.45 P.M.	,,	S.E.	Gale.	20.6	18.1	2.5
,,		7	0.30 P.M.	Clear.	E.	Strong.	23.8	21.7	2.1
,,		,,	6. P.M.	,,	E.	,,	22.0	20.3	1.7
,,		8	7.40 A.M	Rainy.	E.S.E.	Gale.	21.4	20.0	1.4
,,		,,	0.5 P.M.	Cloudy.	E.S.E.	,,	22.7	20.4	2.3
,,		9	7.20 A.M.	Clear.	S.E.	,,	22.4	20.5	1.9
,,		,,	5. P.M.	,,	S.E.	,,	20.5	20.1	0.4
,,		10	7.20 A.M.	,,	S.E.	,,	20.8	20.5	0.3
,,		,,	2. P.M.	,,	S.E.	,,	22.0	19.0	3.0
,,		11	*	Rainy.	S.E.	,,	23.2	19.6	2.6
,,		12		,,	S.E.	Strong.	22.1	18.2	3.9
,,		13		,,	S.E.	Gale.	22.8	19.0	3.8
,,		14		,,	S.E.	Moderate.	24.0	20.0	4.0
			Mean.	.....	.....	.....	**21.9**	**20.0**	(−) **1.9**
,,		15		Cloudy.	S.E.	Light.	26.2	21.1	5.1
,,		16		Clear.	N.W.	Moderate.	26.0	22.0	4.0
,,		17		,,	Calm.	—	21.0	22.1	1.1
,,		18		,,	N.W.	Lihgt.	21.0	21.8	0.8
,,		19		,,	W.	Moderate.	22.2	22.6	0.4
,,		20		Cloudy.	S.E.	Strong.	22.6	22.4	0.2
,,		21		,,	S.E.	,,	22.9	21.2	1.7
,,		22		,,	Calm.	—	24.2	21.2	3.0
,,		23		Rainy.	W.	Light.	20.7	21.3	0.6
			Mean.	.....	.....	.....	**23.0**	**21.7**	(−) **1.2**

TABEE XIII. (*Cont.*)

Place of observation.	Month.	Day.	Time.	Weather.	Wind.		Temperature.		
					Direction.	Intensity.	Air.	Water.	Difference.
							C.°	C.°	
West Kohan.	VIII	24		Clear.	N.W.	Light.	21.6	23.8	2.2
„		25		Cloudy.	S.E.	Moderate.	22.3	22.4	0.1
„		26		„	S.E.	„	—	—	—
„		27		Fair.	E,	„	—	—	—
„		28		„	E.	„	—	—	—
„		29		Rainy.	S.W.	Strong.	23.1	23.7	0.6
„		30		Cloudy.	S.W.	„	21.3	24.0	2.7
„		31		„	S.	Moderate.	22.8	23.4	0.6
			Mean.	.....	.....	.....	**22.2**	**23.3**	(+) **1.2**
„	IX	1		Rainy.	S.E.	Light.	17.8	21.3	3.5
„		2		Cloudy.	W.	Moderate.	21.3	22.6	1.3
„		3		„	Calm.	—	18.9	21.0	2.1
„		4		„	S.E.	Moderate.	19.2	21.3	2.1
„		5		Rainy.	S.E.	Light.	20.4	22.6	2.2
„		6		„	N.W.	„	20.1	22.4	2.3
„		7		„	S.E.	Strong.	19.8	21.9	2.1
„		8		Cloudy.	E.	Moderate.	21.5	22.0	0.5
„		9		„	W.	Light.	19.8	22.0	2.2
„		10		„	S.	Moderate.	19.6	21.4	1.8
			Mean.	.....	.....	.....	**19.8**	**21.9**	(+) **2.0**
Tokotan.	XI	8	9.50 A.M.	Cloudy.	—	—	10.0	13.2	3.2
„		9	10. A.M.	„	N.	Strong.	7.6	12.0	4.4
Takinoue.		10	9.15 A.M.	Clear.	Calm.	—	6.6	12.0	5.4
„		11	9. P.M.	Snowy.	N.E.	Strong.	7.2	11.7	4.5
			Mean.	.....	.....	.....	**7.9**	**12.2**	(+ **4.4**

* Between Aug. 11th and Sept. 10th, the temperature measurement was made at 11 A.M. each day.