crust spanning over the more or less vacant lava "reservoir," this being probably the main cause of the volcanic after-shocks. Hence, the 1st displacement of the principal or maximum vibration of a volcanic fore-shock ought most naturally to be directed outwards, and that of volcanic after-shocks to be directed origin-wards, as illustrated diagrammatically in figs. 13 and 14. This directional difference is in harmony with the results of the instrumental observations in Kagoshima (§ 51), where the 1st displacement of the principal portion of the fore-shocks was mostly directed towards the S.W., and that of the after-shocks mostly toward the N.E.

In the above considerations respecting the direction of motion, it is assumed that the application of the volcanic tension from below did not result in a marked upheaval of a small central area, in which case the 1st displacement ought to be directed inwards, being virtually the first stage in a volcanic explosion.

CHAPTER V. TROMOMETER OBSERVATION IN KAGOSHIMA OF THE SAKURA-JIMA AFTER-ERUPTIONS, JAN. 16TH—FEB. 8TH, 1914.

54. *Observation in Kagoshima.* The compound of the Kagoshima prefectural office, where the tromometer observation has been carried on (§ 30), is situated 10 km. nearly westwards from the centre of Sakura-jima. Its position relative to the craterlets on the two sides of the volcano, which were active at the time concerned, was as follows :—

5.9 km.	to the W.	5° N.	from the	Lowest Craterlet on the W. flank ;
8.5 km.	„ W.	8° N.	„	Highest „ „ ;
11.8 km.	„ W.	10° N.	„	No. 2. Craterlet on the S.E. flank ;
14.3 km.	„ W.	11° N.	„	Lowest „ „ .

The No. 2 and the lower craterlets on the S.E., or the Nabeyama, side remained active for different long time intervals, while the craterlets on the W. side of the island ceased to be active on or about the 25th of January (1914).

The two pointers of the tromometer were arranged so as to register the motion in the directions W.8°N.–E.8°S., and S.8°W.–N.8°E. These corresponded, with regards to the craterlets, approximately to the longitudinal and the transverse components respectively. In the following §§ are described the instrumental diagrams of a number of the more prominent after-eruptions observed in Kagoshima between Jan. 16th and Feb. 8th, 1914.

55. *After-eruptions on evening of Jan. 16th*, 1914. The maximum movements in some of the larger disturbances were as follows:

Longitudinal Component.	Transverse Component.
0.054 mm.	0.051 mm.
0.054 „	0.047 „
0.042 „	
0.041 „	

56. *Jan. 17th*, 1914; 6.29.03 P.M. The very 1st displacement was 0.0086 mm. toward S. 47°E. [Longit. compt.] During the 1st 2.8 sec., the motion was very small. During the next 4.3 sec.: T=0.6 sec., $2a$=0.017 mm. Motion large for the next 21.5 sec.: T=1.3 sec., $2a$=0.041 mm. In the subsequent portion: T=2.5 sec., T=1.2 sec., etc. [Transv. compt.] During the 1st 2.8 sec., the motion was small and slow. For the next 6.9 sec., the motion was small, but active: T=0.44 sec., $2a$=0.022 mm.; T=0.88 sec. During the next 17.5 sec., the motion was large and composed of slow vibrations of T=1.8 sec. ($2a$=0.048 mm,) mixed at first with those of T=0.57 sec. In the subsequent portion: T=2.7 sec., T=1.4 sec., etc.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor,	2.8 sec.	2.8 sec.
„ „ princ. portion,	—	36.0
„ „ specially active part,	24.0	16.6
Total duration,	over 91.0	73.0

57. *Jan.* 17*th*, 1914; 6.17.25 P.M. The very 1st displacement was 0.002 mm. directed toward, and the 2nd was 0.01 mm. away from, the Sakura-jima. The distinct motion occurred 6.2 sec. earlier in the longit. than in the transv. component. [Longit. compt.] For the 1st 5.5 sec.: $T=0.9$ sec., $2a=0.01$ mm. In the principal portion: $T=1.11$ sec., $2a=0.036$ mm. [Transv. compt.] The preliminary tremor lasted 6.2 sec. Max. $2a=0.03$ mm., $T=1.0$ sec.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion,	41.2 sec.	37.2 sec.
Duration of specially strong portion	21.2	21.0

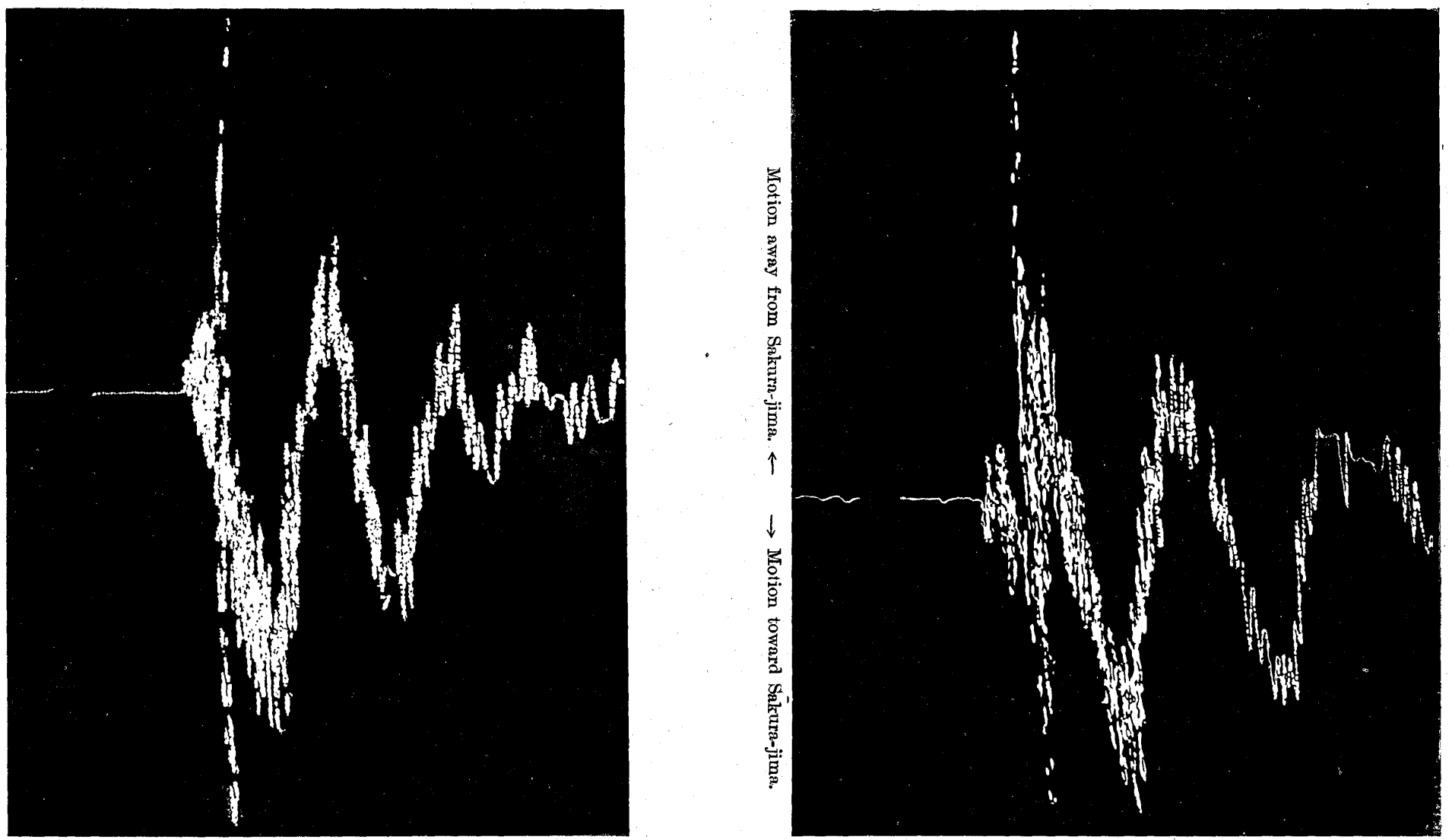
58. *Jan.* 17*th*, 1914; 7.13.17 P.M. The 1st displacement was 0.01 mm. directed away from the Sakura-jima. The motion became distinct 4.5 sec. earlier in the longit. than in the transv. component. [Longit. compt.] The motion was definite from the commencement, giving no distinction between the prel. tremor and the princ. portion. $T=1.03$ sec., $2a=0.02$ mm. [Transv. compt.] Max. $2a=0.017$ mm., $T=0.98$ sec.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion,	16.4 sec.	11.4 sec.
Total duration,	32.0	27.0

59. *Jan.* 18*th*, 1914; 6.57.04 P.M. The 1st displacement was 0.005 mm. directed away from the Sakura-jima. [Longit. compt.] Prel. tremor lasted 4.1 sec. Active motion set in 6.4 sec. after the start. Max. $2a=0.036$ mm., $T=0.90$ sec,; $T=1.52$ sec. [Transv.

Fig. 9. Tromometer Observation in Kagoshima of the Sensible Earthquake on Jan. 23rd, 1914; 8. 51. 55. A. M.

Magnification = 760. (Photographic enlargement.)



(Time-mark Cutting is shown near the left-hand side in each of the diagrams.)

Fig. 15. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 21st, 1914; 2. 07. 26 P.M.

Magnification = 850. (×) Minute Time-cutting. (Photographic enlargement.)

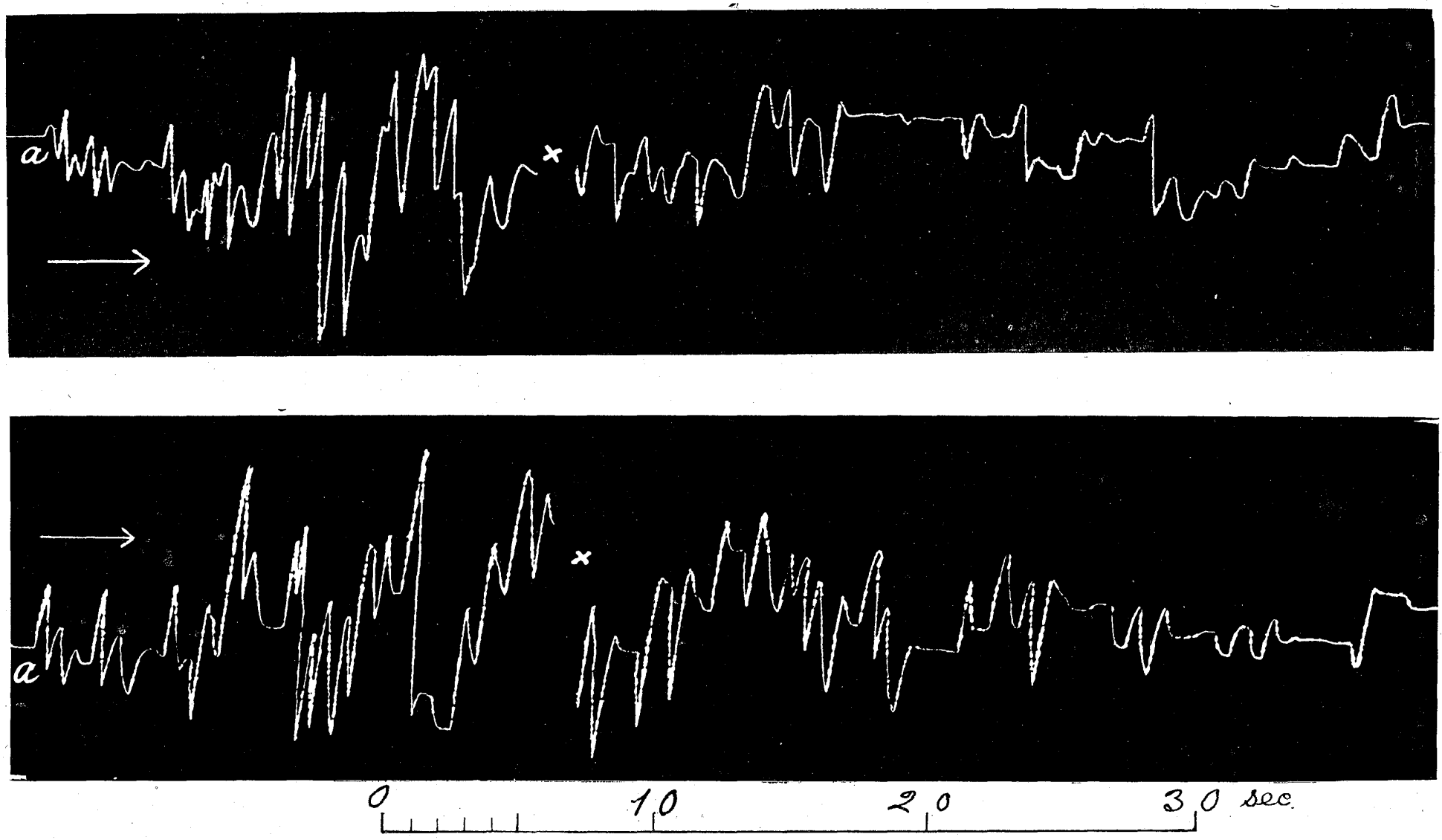


Fig. 16. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan 21st, 1914; 2. 19. 57 P. M.

Magnification = 700. (×) Time Cutting every 1 minute. (Photographic enlargement.)

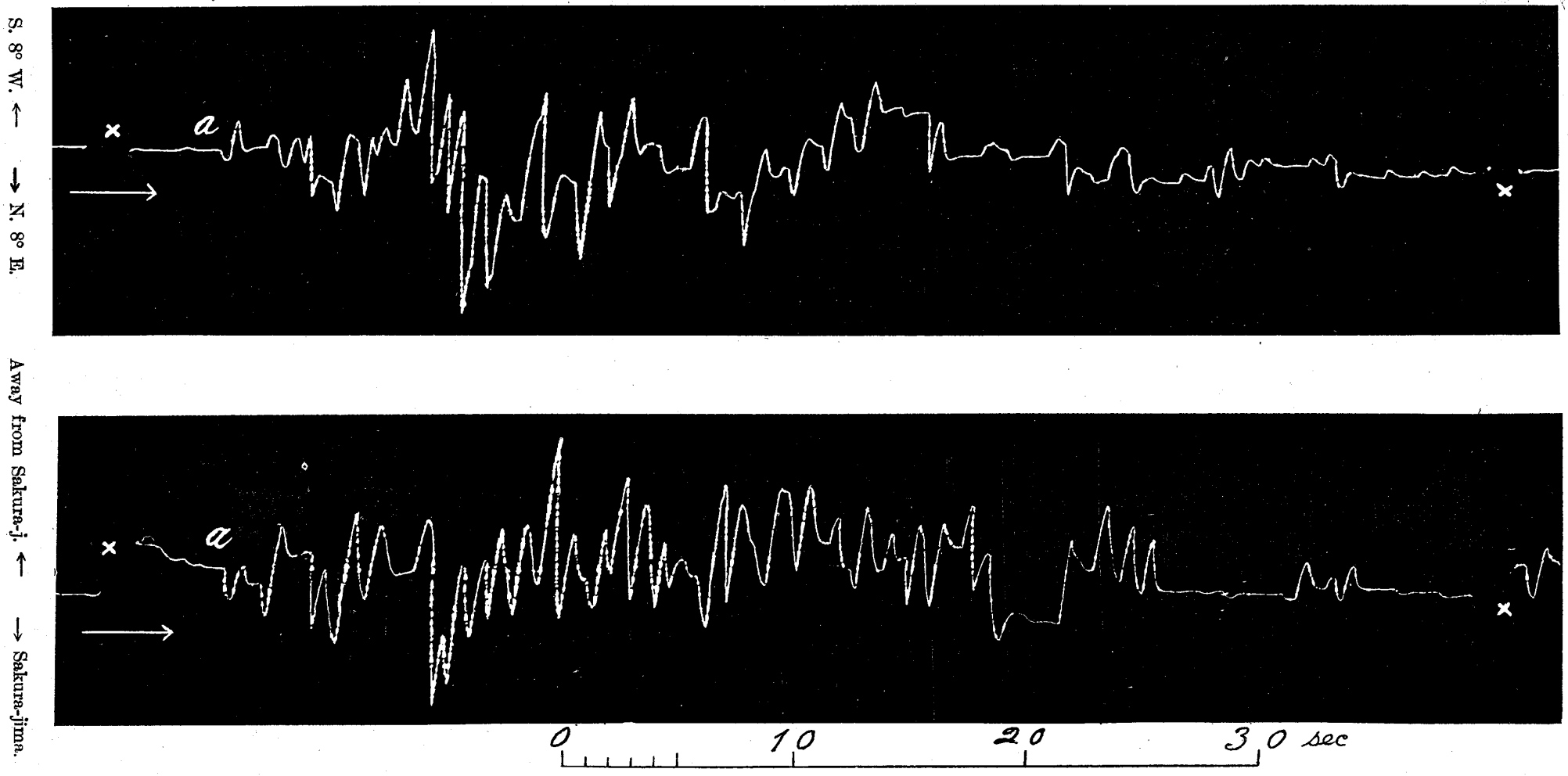


Fig. 17. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 17th, 1914; 6. 29. 03. P. M.

Magnification=950. (×) Minute Time-cutting. (Photographic enlargement.)

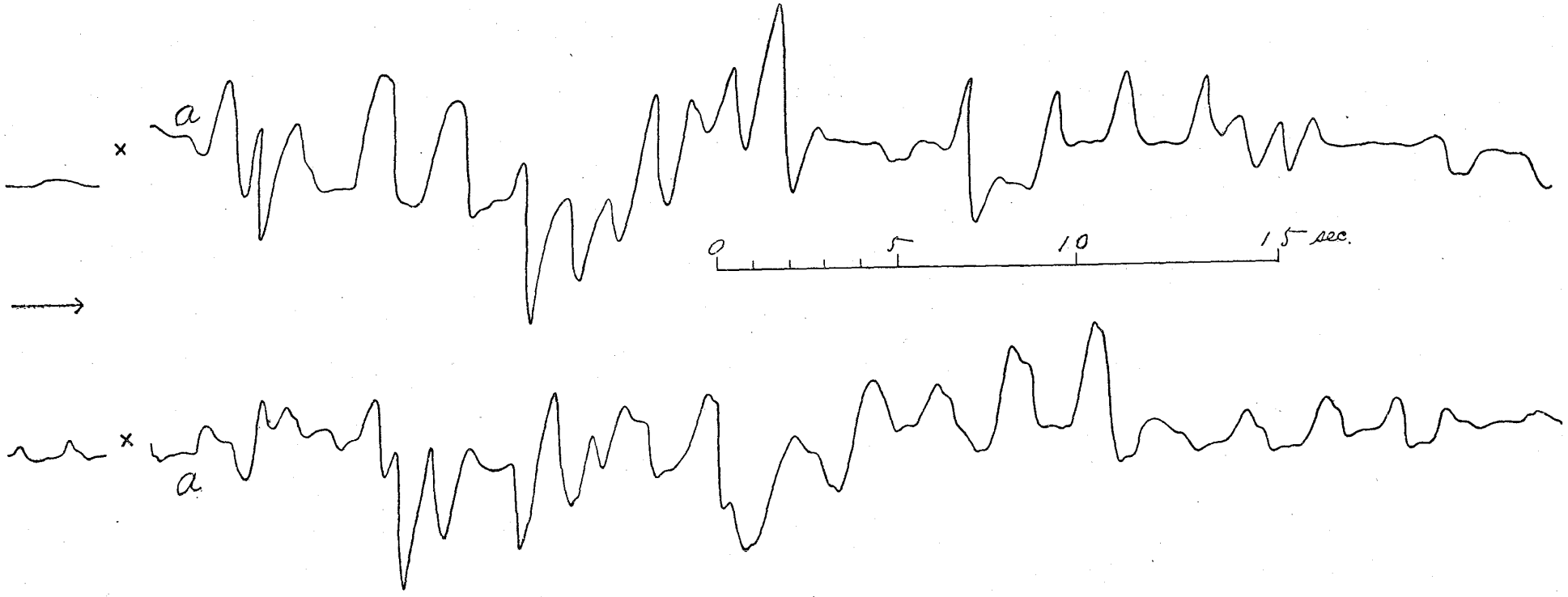


Fig. 18. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1914; 6. 35. P. M.

Magnification = 890. (×) Minute Time-cutting. (Photographic enlargement.)

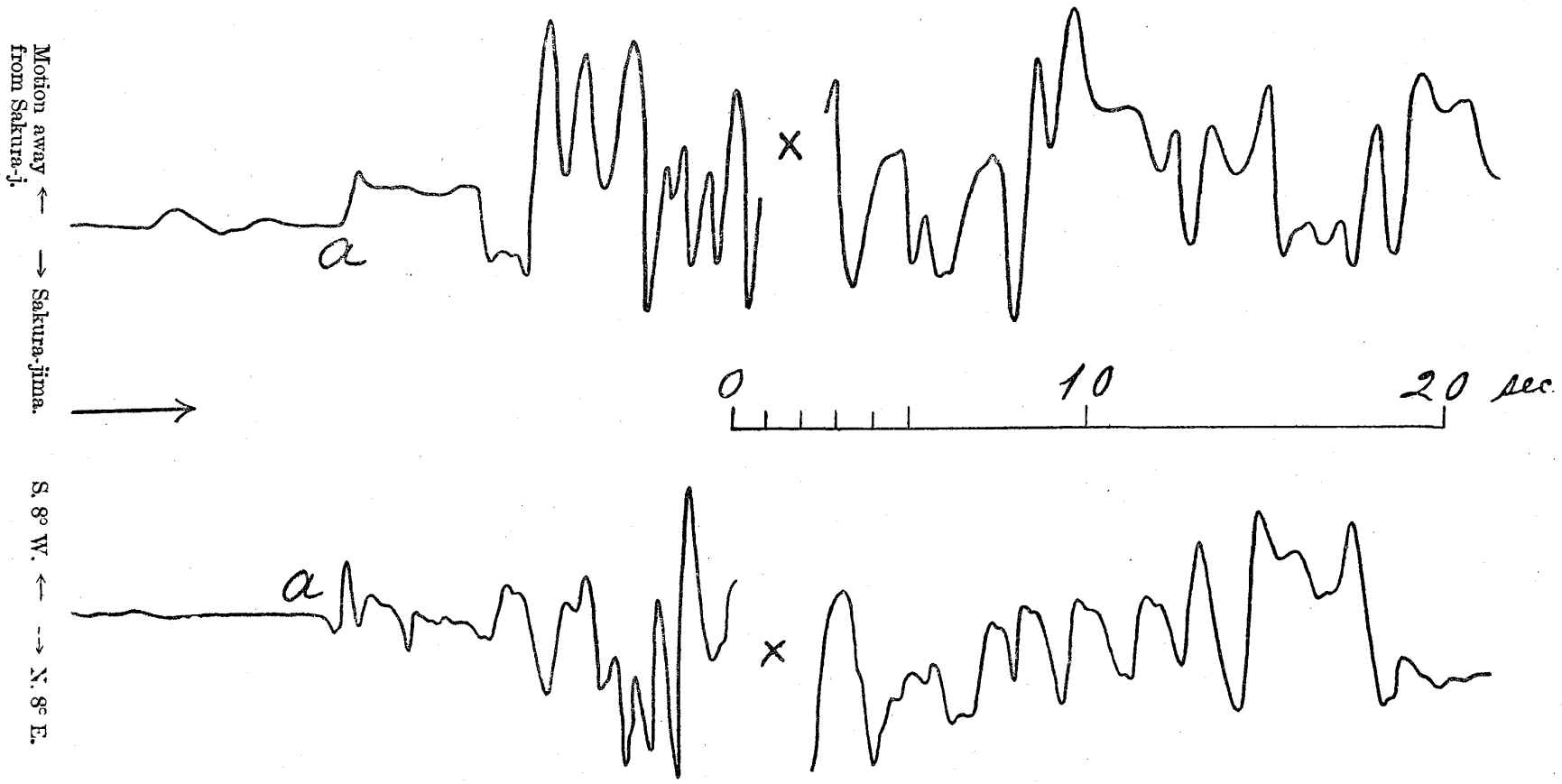
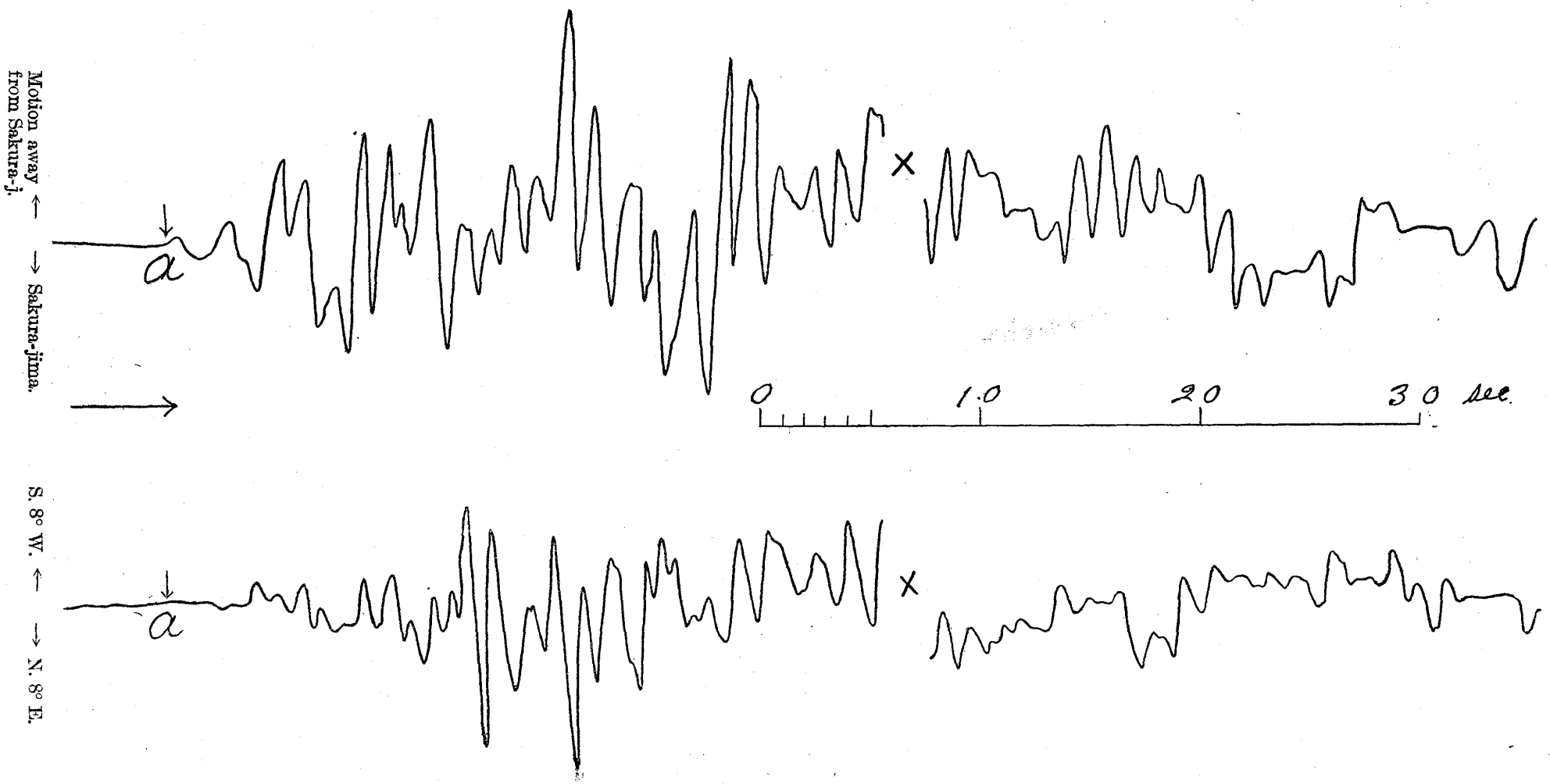


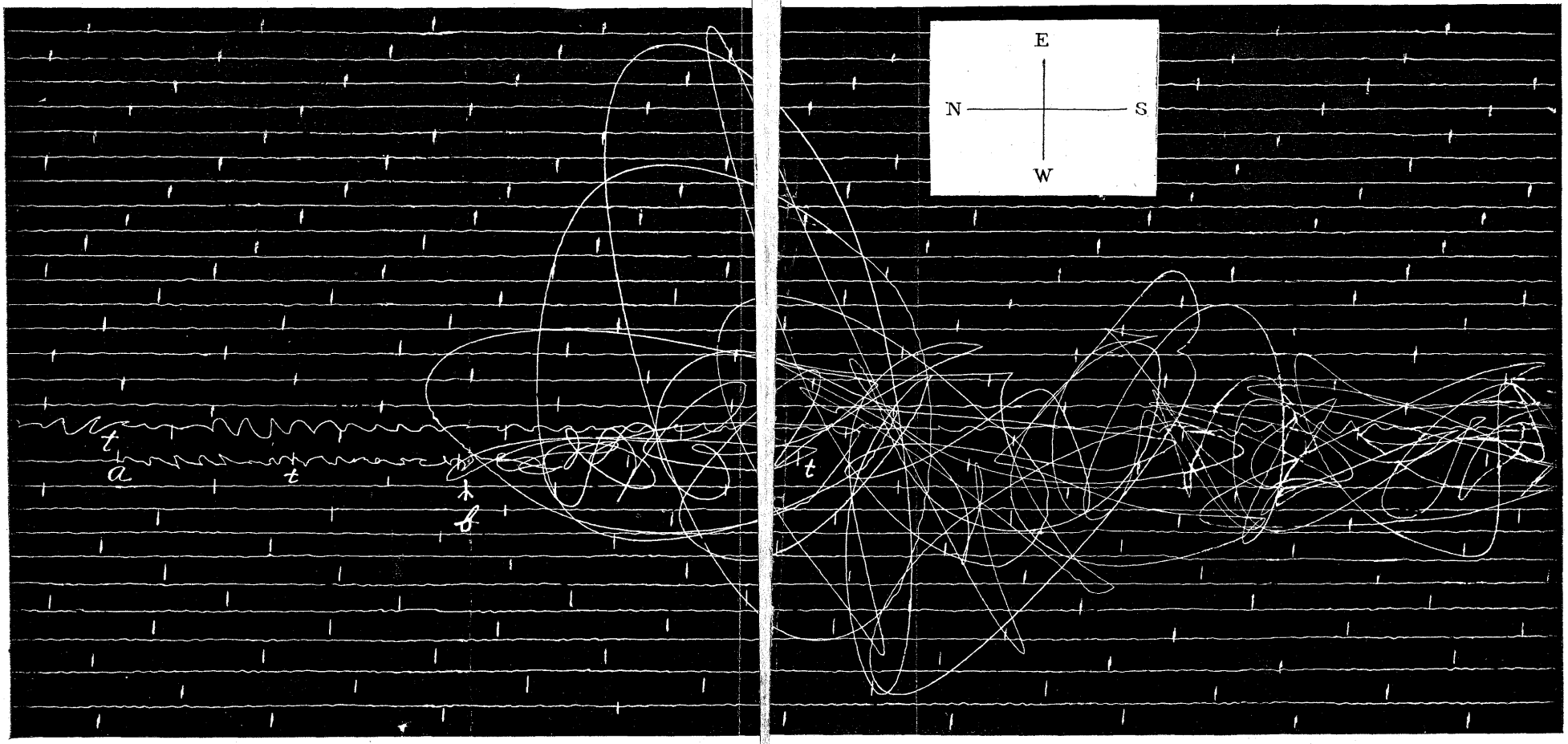
Fig. 19. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1916; 6. 07. 42. P. M.

Magnification=730. (×) Minute Time-cutting. (Photographic enlargement.)



Figs. 2, A and B. Duplex Pendulum Observation in Tokyo of the Sakura-jima Earthquake on Jan. 12, 1914. Magnification=26.

Fig. 2, A.



a.....Commencement of the Earthquake.

Fig. 20. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1914; 7. 15. 40. P. M.

Magnification = 670. (×) Minute Time-cutting. (Photographic enlargement.)

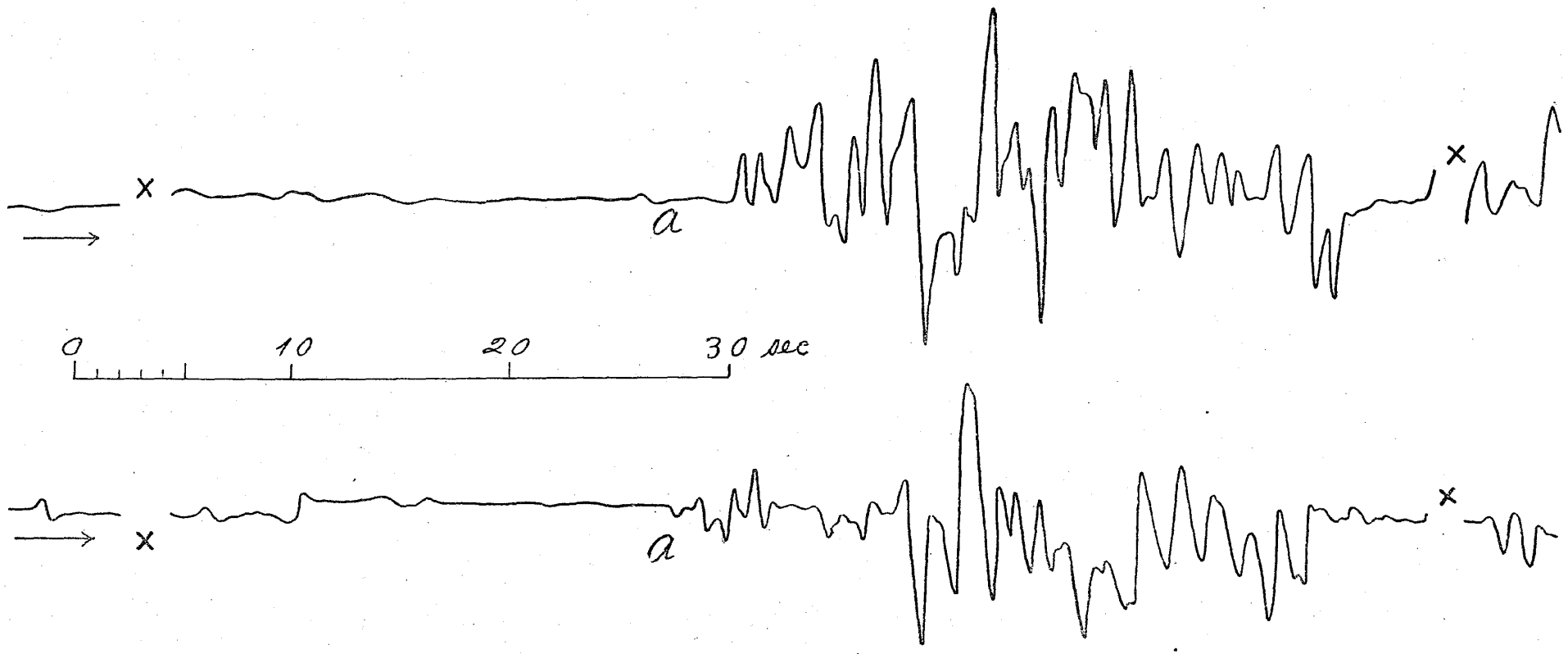
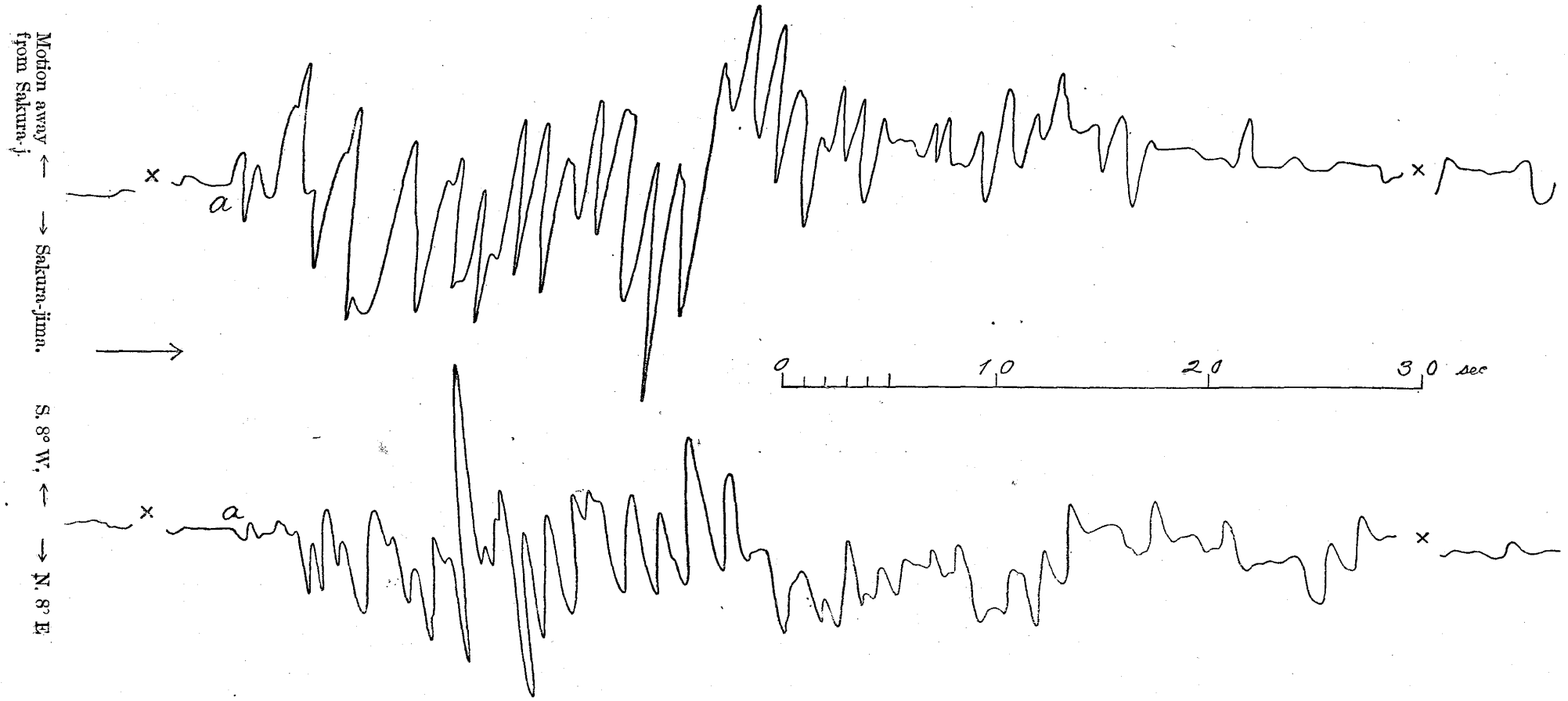


Fig. 21. Tromometer Observation in Kagoshima of the Sakura-jima After-eruption on Jan. 18th, 1914; 6. 34. 04. P. M.

Magnification=700. (×) Minute Time-cutting. (Photographic enlargement.)



compt.] Prel. tremor lasted 4.1 sec. Max. motion,=0.03 mm., occurred 10.5 sec. after the start. T=0.91 sec.; T=1.56 sec.

	Longit. Compt.	Transv. Compt.
Duration of principal portion,	27.5 sec.	26.0 sec
„ spec. active portion,	13.7	10.7
Total duration,	62.0	53.0

60. *Jan.* 18*th*, 1914; 8.20.44 P.M. A small disturbance, which lasted 21 sec. and 17.7 sec. in the longit. and the transv. components respectively, and then abruptly ended. The definite motion in the longitudinal occurred 3.5 sec. earlier than that in the transverse component.

Longit. compt. .... Max. $2a$=0.018 mm., T=1.57 sec.; T=2.05 sec.
Transv. compt. .... „ =0.015 „. T=1.95 „ .

61. *Jan.* 19*th*, 1914; 6.50. A.M. This was a fairly large disturbance whose 1st motion was very small and directed toward the origin, and whose 2nd motion was 0.0076 mm. due west, (The diagram has been given in the Bulletin Vol. VIII, No. 1.) The motion became distinct in the transverse component 4.8 sec. later than in the longitudinal. The max. transv. displacement occurred 13.8 sec. after the start.

	Longit. Compt.	Transv. Compt.
Prel. Tremor,	Dur.=5.5 sec. $2a$=0.012 mm.	Dur.=6.3 sec. Motion very small.
Dur. of princ. portion,	46.5 sec.	40.5 sec.
Dur. of spec. strong part,	26.0 „	15.0 „
Total duration,	114.0 „	114.0 „
Max. $2a$,	0.055 mm.	0.050 mm.
T,	1.13 sec.	1.15 sec.

62. *Jan.* 19*th*, 1914; 5.16.38 A.M. The preliminary tremor lasted 4.0 sec. in each component, the 1st displacement being

directed away from the Sakura-jima. In the transv. component, the motion was small for 6.8 sec. The max. longit. and the max. transv. displacements occurred respectively 15.2 and 11.3 sec. after the commencement.

	Longit. Compt.	Transv. Compt.
Duration of princ. portion	41. sec.	37 sec.
Total duration, ...	114 „	—
Max. $2a$, ...	0.038 mm.	0.045 mm.
T, ...	0.90 sec.; 1.26 „	0.91 sec. 1.10 „

63. *Jan.* 19*th*, 1914; 4.47.00 A.M. The longit. and the transv. vibrations remained small for the first 8.5 and 6.0 sec. respectively; the motion becoming distinct in the former component 2.6 sec. earlier than in the latter. The longit. motion was most active during the interval of 17.5 to 26.5 sec. from the commencement, max. displacements also occurring 8.5 and 12.0 sec. after the same time moment. The max. transv. epoch set in 14.7 sec. after the commencement, when the longit. motion was at a minimum.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor,.....	3.0 sec.	3.5 sec.
„ „ princ. portion, ...	28.5 „	27.5 „
„ „ spec. strong part,..	21.0 „	13.0 „
Total duration, ...	100.0 „	——
Max. $2a$, ...	0.05 mm.	0.046 mm.
T, ...	0.91 sec.	0.88 sec. 1.77 „

64. *Jan.* 19*th*, 1914; 7.37.41 A.M. In the transverse component, the motion remained small for the 1st 8.4 sec., and the max. displacement occurred 10.1 sec. after the commencement.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	——	3.0 sec.
„ „ princ. portion, ...	42.0 sec.	40.0 „
„ „ spec. strong part, ..	27.5 „	23.0 „
Total duration, ...	67.0 „	67.0 „
Max. $2a$, ...	0.044 mm.	0.042 mm.
T, ...	1.07 sec. 1.03 „	0.86 sec. 1.24 „

65. *Jan.* 19*th*, 1914; 8.48.36 P.M. There is a doubtful trace of prel. tremor of 5.5 and 2.5 sec. duration in the transv. and longit. components respectively. The moments of the commencement when the motion became distinct were as follows:—

Longitudinal, 8. 48. 36.4 P.M. Transverse, 8. 48. 39.8 P.M.

Thus the longit. motion occurred 3.4 sec. earlier than the transverse. [Longit. compt.] Duration of princ. portion=13.5 sec. Total duration=27 sec. The most active portion, $2a$=0.015 mm., T=1.25 sec., occurred 9.4 sec. after the commencement. [Transv. compt.] Princ. portion lasted 14.4 sec., the max. displacement of 0.013 mm. having occurred 5.0 sec. after the commencement. T=0.86 sec. After the princ. portion, the motion was practically *nil.*

The elements of motion in some of the other after-eruptions on Jan. 19th are given in Table XVIII.

66. *Jan.* 21*st*, 1914; 8.44.38 P.M. In the longitudinal direction, the prel. tremor lasted 10.9 sec.: T=2.4 sec. The principal portion began simultaneously in the two components, the longit. displacement at the beginning being 0.013 mm. toward the Sakura-jima, corresponding to a complete oscillation in the transv. component composed of the two displacements of 0.005 mm. toward S. 8° W. and of 0.006 mm. toward N. 8° E.

	Longit Compt.	Transv. Compt.
Duration of princ. portion, ...	11.5 sec.	11.0 sec.
Max. 2a, ...	0.029 mm.	0.017 mm.
T, ...	1.2 sec.	{ 1.4 sec. 0.7 „

TABLE XVIII. ELEMENTS OF MOTION IN SOME OF THE AFTER-ERUPTIONS OBSERVED ON JAN. 19TH AND 21ST, 1914.

Date (Jan. 1914.)	Time of Occurrence.	Longitudinal Component.				Transverse Component.			
		Duration of		Max. Motion.		Duration of		Max. Motion.	
		Princ Portion.	Total Disturbance.	$2a$	T	Princ Portion.	Total Disturbance.	$2a$	T
		sec.	sec.	mm.	sec.	sec.	sec.	mm.	sec.
19	2.36.10 A.M.[1]	25.5	69	0.025	1.1	—	—	0.028	{ 0.88 1.7
„	3.49.57 „	22.0	38	0.027	1.02	22.0	—	0.025	1.0
„	6.05.01 „	28.0	80	0.035	1.24	—	—	0.024	1.1
„	6.31.46 „ [2]	27.5	75	0.038	1.2	28.0	—	0.038	1.14
„	8.00.11 „	42.5	—	0.038	1.16	31.0	—	0.038	{ 0.80 1.21
„	8.08.31 „ [3]	—	—	0.037	{ 0.92 2.6	63.0	97	0.036	{ 0.9 2.5
„	8.49.26 P.M.	—	—	—	—	—	10.3	0.005	1.6
„	8.55.32 „	—	—	0.01	—	8.8	—	0.011	—
21	3.41.23 A.M [4]	38.0	107	0.05	1.03	34.0	77	0.057	0.83
24	11.29.35 „	—	31	0.029	0.9	—	34	0.024	{ 0.58 1.2

(1) Duration of prel. tremor (*longit.*) = 6.2 sec.
(2) „ „ „ „ (*transv.*) = 14.2 sec.
(3) Duration of specially active part = 18.4 sec. (*longit.*), 17.4 sec. (*transv.*).
(4) „ „ „ „ „ = 14.0 sec. „ 8.1 sec. „

67. *Jan. 21st*, 1914; 10.11.53 P.M. The longit. motion began 2.7 sec. earlier than the transverse, and the 1st displacement was 0.006 mm, directed away from the Sakura-jima. [Longit. compt.] For the 1st 6.1 sec., the motion was small and composed ef $2\frac{1}{2}$ slow oscillations of $T = 2.6$ sec. ($2a = 0.018$ mm.) mixed with smaller and quicker movements. For the next 20.8 sec., the motion was

larger: $T=2.6$ sec., $2a=0.032$ mm.; $T=1.04$ sec., $2a=0.026$ mm. [Transv. compt.] Motion small for the 1st 5.8 sec.; $T=2.3$ sec., $2a=0.017$ mm.; $T=0.73$ sec. For the next 8.1 sec., the motion was larger, and composed of $4\frac{1}{2}$ vibrations of $T=1.8$ sec., $2a=0.028$ mm. The subsequent motion was much smaller: $T=2.1$ sec., $2a=0.016$ mm.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion,	27.0 sec.	23.0 sec.
Duration of spec. strong part, ...	18.6 „	18.7 „
Total duration, ...	38.2 „	34.5 „

68. *Jan.* 21*st*, 1914; 2.07.26 P.M. The longitudinal motion began 1.0 sec. earlier than the transv. The 1st displacement was 0.032 mm. toward S. 85° W. The first max. motion, which occurred at the commencement of the principal portion of the transverse component, was 0.048 mm. toward N. 58° E. [Longit. compt.] Motion small for the 1st 7.0 sec.: $T=0.78$ sec., $2a=0.017$ mm. For the next 7.5 sec. the motion was most active ($T=0.7$ sec.), beginning with an outward displacement of 0.033 mm. The two max. movements of 0.037 mm. and 0.046 mm. occurred respectively 9.9 sec. and 14.2 sec. after the commencement. Thereafter the period was $T=0.8$ sec. ($2a=0.026$ mm.). At the end, the motion was slow: $T=1.25$ sec. [Transv. compt.] Motion small for the 1st 4.3 sec.: $T=0.61$ sec., $2a=0.01$ mm. For the next 4.4 sec., the motion was a little larger: $T=0.73$ sec., $2a=0.016$ mm. Then there followed for 2.0 sec. the most active part: $T=0.67$ sec., $2a=0.043$ mm. Thereafter slow movements of $T=1.27$ sec. were mixed with those of $T=0.66$ sec. ($2a=0.031$ mm.).

	Longit. Compt.	Transv. Compt.
Duration of princ. portion, ...	31.0 sec.	25.4 sec.
„ „ spec. strong part, ...	17.7 „	12.2 „
Total duration, ...	66.0 „	55.0 „

69. *Jan. 22nd*, 1914; 2.54.18 A.M. This was a fairly large disturbance, of the total duration of 76 sec. The princ. portion lasted 47 and 44 sec. respectively in the longit. and the transv. components. The very 1st displacement was small and directed toward Sakura-jima, while the 2nd was 0.013 mm. toward N. 54° W. The most active part, which lasted 22 sec., began 6.5 sec. later on, commencing with the longit. displacement of 0.045 mm. toward Sakura-jima, accompanied by two transv. displacements of 0.015 mm. toward N. 8° E. and of 0.013 mm. toward S. 8° W. The max. vibration, which occurred 16.5 sec. after the start, was as follows: $2a=0.047$ mm. toward N. $28°\frac{1}{2}$ W., $2a=0.055$ mm. toward S. $48°\frac{1}{2}$ E. In the transv. component, $T=1.18$ sec., $T=2.24$ sec.

70. *Jan. 22nd*, 1914; 9.38.45 A.M. Total duration = 64 sec.; duration of princ. portion=38 sec. The 1st displacement (=0.01 mm.) in the longit. component occurred 1.3 sec. earlier than in the transverse, and was directed away from Sakura-jima. Max. displacement in each component was 0.037 mm. (slow motion), and 0.02 mm. (quick motion).

71. *Jan. 22nd*, 1914; 10.45.20 A.M. Total duration =32.3 sec. The 1st displacement (=0.013 mm.) in the longit. component occurred 2.2 sec. earlier than in the transverse, and directed away from Sakura-jima.

Longit. Max. $2a=0.025$ mm., $T=1.04$ sec., $T=1.16$ sec.
Transv. „ $=0.023$ „ , $T=1.02$ sec., $T=0.75$ sec.

72. *Jan. 22nd*, 1914; 11.44.43 A.M. The 1st displacement was 0.011 mm. toward S. 70° W. The motion became well pronounced 4.0 sec. earlier in the longit. than in the transv. component.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	— sec.	4.0 sec.
„ princ. portion, ...	26.5 „	22.0 „

Total duration, ...	51.0 sec.	—
Max. $2a$, ...	0.028 mm.	0.024 mm.
T, ...	0.77 sec.	0.77 sec.

73. *Jan. 22nd*, 1914; 1.10.28 P.M. Definite movements occurred 2.5 sec. earlier in the longit. than in the transv. component.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	—	4.4 sec.
„ princ. portion, ...	36.5 sec.	28.2 „
Total duration, ...	57.5 „	47.3 „
Max. $2a$, ...	0.023 mm.	0.024 mm.
T, ...	0.85 sec.	—

74. *Jan. 22nd*, 1914; 7.47.50 P.M. This was a very small disturbance composed of slow movements, and was due to an outburst whose loud detonation was perceived in Kagoshima (at the Satsumaya Hotel) at about 7.47.50 P.M. The 1st definite motion occurred 2.8 sec. earlier in the longit. than in the transv. component. Total duration =32 sec. [Longit. compt.] The princ. portion appeared 5.4 sec. after the commencement: max. $2a=0.012$ mm., $T=1.9$ sec. [Transv. compt.] Max. $2a=0.008$ mm., $T=1.8$ sec.

75. *Jan. 23rd*, 1914; 2.20.20 A.M. Also a small and very slow disturbance, due to an outburst whose loud booming sound was perceived in Kagoshima at 2.20.37 A.M. The longit. motion occurred 7.0 sec. earlier than the transverse, the 1st displacement being 0.0015 mm. toward, and the 2nd 0.006 mm. away from Sakura-jima. [Longit. compt.] Total duration =45.5 sec. Motion small for the 1st 8.0 sec. The princ. portion lasted 15.0 sec.: $T=1.9$ sec., $2a=0.014$ mm.; $T=1.28$ sec., $2a=0.012$ mm. [Transv. compt.] Total duration=27 sec., no prel. tremor being indicated. The princ. portion lasted 16 sec, and was nearly uniform: $T=2.0$ sec., $2a=0.014$ mm.; $T=0.68$ sec.

76. *Jan. 24th*, 1914; 6.28.43 P.M. The 1st distinct displacement was 0.006 mm. toward S. 48° E.

	Longit. Compt.	Transv. Compt.
Duration of princ. portion, ...	32.7 sec.	19.8 sec.
Total duration, ...	—	67.0 „
Max. 2a, ...	0.023 mm.	0.027 mm.
T, ...	0.91 sec.	0.73 sec.; 1.2 sec.

77. *Jan. 24th*, 1914; 3.28.54 P.M. [Prel. tremor.] The 1st motion was directed away from Sakura-jima, and=0.009 mm., accompanied by a transverse vibration composed of two displacements of 0.002 mm. toward N. 8° E. and of 0.002 mm. toward S. 8° W. *Longit.*: T=0.94 sec., $2a$=0.009 mm. *Transv.*: T=0.73 sec., $2a$=0.005 mm. [Princ. portion.] The 1st displacement was 0.02 mm. toward N. 60° E. *Longit.*: duration=21.8 sec., T=1.04 sec. *Transv.*, duration=22.2 sec., T=0.89 sec.

78. *Jan. 26th*, 1914; 11.18.57 P.M. Total duration = 43 sec., duration of princ. portion=23 sec. *Longit.*: T=0.9 sec., $2a$=0.017 mm. *Transv.*: T=0.8 sec., $2a$=0.023 mm.

79. *Jan. 26th*, 1914; 2.41.04 A.M. Total duration =69 sec.; duration of princ. portion=27.5 sec. Definite motion in the longit. occurred 5.0 sec. earlier than in the transv. component, *Longit.*, T=0.97 sec., $2a$=0.024 mm.; *transv.*, T=0.91 sec., $2a$=0.022 mm.

80. *Jan. 26th*, 1914; 3.46.59 A.M. Total duration =68 sec.; duration of princ. portion=24 sec. The well defined princ. portion began 6.5 sec. earlier in the longit. than in the transv. component, the 1st displacement of this stage being 0.015 mm. toward S. 88°W. The max. longit. motion of 0.034 mm. occurred 17.5 sec. after the commencement of the princ. portion. *Longit.*, T=1.33 sec,, $2a$=0.034 mm.; *transv.*, T=1.35 sec., $2a$=0.031 mm.

81. *Jan. 26th*, 1914; 6.01.33 A.M. Total duration=54 sec.; dura-

tion of the prel. tremor = 9.0 sec. The princ. portion in the longit. occurred 4.9 sec. earlier than that in the transv. component. *Longit.*, T = 1.03 sec., $2a$ = 0.019 mm. ; *transv.*, T = 1.03 sec., $2a$ = 0.024 mm.

82. *Jan. 26th*, 1914 ; 9.00.09 A.M. The disturbance was very small and slow and was due to an outburst which caused a strong detonation with shaking effects perceived in Kagoshima (at the Satsumaya Hotel) at 9.01.01 A.M.

	Longit. Compt.	Transv. Compt.
Duration of princ. portion,	48.5 sec.	46.5 sec.
Total duration,	over 88. „	91. „
Time of commencement,	9.00.09 A.M.	9.00.09 A.M.
Motion slightly increased at	9.00.17	9.00.15½
„ became definite at	9.00.23,6	9.00.29,4
Maximum portion began at	9.00.34,8	9.00.40,3
„ ended at	9.01.18,6	9.01.26,8

[Longit. compt.] During the 1st 31 sec. of the princ. portion, T = 2.4 sec., $2a$ = 0.016 mm. Thereafter, T = 1.26 sec., $2a$ = 0.019 mm. [Transv. compt.] T = 2.6 sec. ; T = 1.4 sec., $2a$ = 0.012 mm. ; T = 0.66 sec.

83. *Jan. 29th*, 1914 ; 10.51.03 P.M. The motion became definite in the transv. component 2.6 sec. later than in the longit. The very 1st quick displacement was 0.013 mm. directed away from Sakura-jima, while the two slow vibrations at the commencement were composed of the following displacements :—

1st Slow Vibration	1st displt.,	0.015 mm.,	toward due west.
	2nd „	0.018 „ ,	„ due east.
2nd Slow „	1st „	0.032 „ ,	„ S. 55°W.
	2nd (max.)	0.033 „ ,	„ N. 70°E.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor,	3.3 sec.	—
„ princ. portion,	24.7 „	19.7 sec.
Total duration,	35.0 „	—

Quick vibration	T,	0.94 sec.	0.92 sec.
	Max. $2a$,	0.024 mm.	0.019 mm.
Slow vibration, T,		2.1 sec.	1.9 sec.

84. *Photographic enlargements.* In §§ 85 to 89 are given the results of analysis of the photographically enlarged copies of the diagrams of the following 5 after-eruptions:—

Jan. 17th, 1914; 10.41.58½ P.M.
„ 18th, „ ; 6.07.42 „
„ ; 6.34.04 „
„ ; 7.15.40 „
„ 21st, „ ; 2.19.57 „

The motion consisted of slow vibrations, as was the case with the shakings of the ground caused by the Asama-yama explosions. (See the Bulletin, Vols. VI and VII.) Illustrative diagrams are reproduced in figs. 15 to 21 (Pls. LXXIX to LXXXV).

85. *Jan. 17th*, 1914; 10.41.58½ P.M. This was due to an outburst from one of the W. side craterlets, whose strong detonation was perceived by the author at 10.42.13 P.M. at the Satsumaya Hotel in Kagoshima.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor and princ. portion,	16.8 sec.	21.2 sec.
Duration of most active part,	—	11.0
Total duration,	68.	60.

The very first displacement was directed radially outwards from Sakura-jima, and the transverse component was nearly zero during the first 1.5 sec. [Longit. compt.] For the first 2.5 sec.: T= 1.01 sec., $2a$=0.016 mm. For the next 6.5 sec., the motion was comparatively slow: T=2.15 sec., $2a$=0.018 mm. Then, for 7.8 sec., the motion was most active and regular (T=1.2 sec.) and indicated the following two maximum movements at the commencement and

the end :—

1st Displacement 0.032 mm., toward S. 40°E.
Last „ 0.028 „ , „ S. 86°E.

This portion was essentially longitudinal in character, but for the next 4.4 sec., the longitudinal component was nearly zero. Then at 21.2 sec. after the start, there occurred a well pronounced displacement of 0.020 mm., toward N. 82°E. The subsequent motion was much smaller, there being 6.3 sec. later on a few vibrations of $T=1.06$ sec., $2a=0.01$ mm. [Transv. compt.] During the first 5.7 sec., the motion was small : $T=0.76$ sec., $2a=0.011$ mm. Then there took place a prominent vibration of $T=0.96$ sec., and $2a=0.020$ mm., which was purely transverse ; the corresponding longitudinal component being zero. The motion continued quick in period for the next 4.9 sec. : $T=1.10$ sec., ($2a=0.022$ mm.). For the next 14.7 sec., the motion was large, but slow : $T=2.1$ sec., $2a=0.021$ mm. Thereafter the vibrations were abruptly reduced and remained nearly uniform for 16 sec. : $T=2.1$ sec., $2a=0.01$ mm. The subsequent motion was very small.

86. *Jan.* 18*th*, 1914 ; 6.07.42 P.M. (Fig. 19.) The very first displacement was 0.0013 mm. directed outward from, and the 2nd was 0.0043 mm. toward to, the Sakura-jima radially, the commencement of the longitudinal motion being 2.0 sec. earlier than that of the transverse.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	3.2 sec.	— sec.
„ princ. portion, ...	38.5 „	32.5 „
„ most active part, ...	20.6 „	16.1 „
Total duration, ...	98. „	87. „

The movements during the successive stages were as follows:—

Longitudinal Component.	Transverse Component.
(i). Preliminary Tremor: Duration = 3.2 sec.	
Motion small and composed of two slow vibrations of $T=1.58$ sec., $2a=0.0072$ mm.	Motion very small: $T=0.9$ sec.
(ii). 8.4 sec.	
Slow movements: $T=1.05$ sec., $2a=0.044$ mm.	Quick vibrations: $T=0.84$ sec., $2a=0.014$ mm.
(iii). 3.8 sec.: Motion essentially transverse.	
Motion small: $T=0.93$ sec., $2a=0.019$ mm.	$T=1.10$ sec. The 1st vibration was a maximum, and composed of the two displacements of 0.022 mm. and 0.047 mm. directed toward S. 8° W. and N. 8° E. respectively; the simultaneous longit. component being zero.

(iv). 8.6 sec.: Motion most active and regular.

$T=1.2$ sec. The 1st vibration was a maximum and composed of the following two displacements:—

1st Displacement 0.061 mm., toward N. 34°W.
2nd „ 0.062 „ „ S. 46°E.

The 1st displacement of the last but one vibration, which occurred 21.4 sec. after the start, was the absolute maximum: 0.067 mm. toward N. 75°W.

(v). 23.5 sec.: Motion small.

$T=1.13$ sec., $2a=0.023$ mm.	$T=1.19$ sec., $2a=0.019$ mm.

The subsequent motion was very small.

87. *Jan.* 18*th*, 1914; 6.34.04 P.M. (Fig. 21.) The very 1st two quick displacements were entirely longitudinal, and respectively 0.007 mm. outward from, and 0.015 mm. toward the Sakura-jima. The transverse component became distinct 3.0 sec. later than the longitudinal.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	3.6 sec.	3.6 sec.
„ princ. portion, ...	44. „	37. „
„ specially strong part, ...	30. „	22. „
Total duration, ...	99. „	——

Longitudinal Component.	Transverse Component.
(i). Prel. Tremor: Duration = 3.6 sec.	
T = 0.89 sec., $2a$ = 0.015 mm. Slow vibr., $2a$ = 0.027 „	T = 0.74 sec., $2a$ = 0.0035 mm.
(ii). 7.6 sec.	
T = 2.24 sec., $2a$ = 0.045 mm.	Motion uniform and composed of 3 vibrations of T = 2.35 sec., $2a$ = 0.022 mm. T = 0.78 sec., $2a$ = 0.013 mm.
(iii) Max. Transverse Stage: Duration = 9.1 sec.	
Motion regular: T = 1.32 sec., $2a$ = 0.039 mm.	Begins with the absolute max. $2a$ = 0.06 mm. directed toward S. 8° W., the simultaneous longit. component being zero. T = 1.14 sec.
(iv). Active Longitudinal Stage: Duration = 5.6 sec.	
Motion regular: T = 1.24 sec.	Motion small: T = 1.49 sec., $2a$ = 0.03 mm.

The three successive displacements at the commencement of this portion were as follows :—

1st Displacement = 0.052 mm., toward S. 36°E.
2nd „ = 0.051 „ , „ N. 66°W.
4th „ = 0.052 „ , „ N. 82°W.

(v). 17.8 sec. : Motion smaller.

T=0.93 sec., $2a$=0.021 mm.	T=1.11 sec., $2a$=0.018 mm.

(vi). Motion very small.

	T=1.7 sec.

88. *Jan. 18th*, 1914; 7.15.40 P.M. (Fig. 20.) Total duration= 48 sec.

	Longit. Compt.	Transv. Compt.
Duration of prel. tremor, ...	6.5 sec.	10.7 sec.
„ princ. portion, ...	24.0 „	18.4 „

Longitudinal Component.	Transverse Component.

(i). 10.7 sec.

T=1.01 sec., $2a$=0.034 mm.	T=0.74 sec., $2a$=0.012 mm.

(ii). 5.7 sec.

Begins with the absolute max. displacement : 0.051 mm. toward Sakura-jima, corresponding to	Begins with a max. vibration of the two displacements :— 1st displ. = 0.034 mm., toward N. 8°E. 2nd displ. = 0.027 mm., toward S. 8°W. The slow absolute max. vibr. occurred 13.0 sec. after the start :—

Longit. motion = 0	1st displ. = 0.042 mm., → S.8°W.
,, = 0.043mm. outward	2nd displ. = 0.043 mm., → N.8°E.

The latter gives the resultant motion of
$2a = 0.061$ mm., toward N. 30°W.

$T = 1.15$ sec.	$T = 1.64$ sec.; $T = 0.82$ sec.

(iii). 14.3 sec.

Motion regular and began with a max. vibration:—

1st Displacement = 0.035 mm., toward S. 57°E.
2nd ,, = 0.046 ,, , ,, N. 59°W.

$T = 1.13$ sec.	$T = 1.36$ sec.

The subsequent motion was small.

89. *Jan. 21st*, 1914; 2.19.57 P.M. (Fig. 16.) The very first displacement was 0.0013 mm., directed toward N. 77°E. The disturbance lasted 49 sec. and then ended abruptly.

	Longit. Compt.	Transv. Compt.
Dur. of prel. tremor, ...	1.9 sec.	3.8 sec.
,, princ. portion, ...	31.7 ,,	27.5 ,,
,, specially strong part, ...	12.8 ,,	12.0 ,,

Longitudinal Component.	Transverse Component.

(i). 1st 7.5 sec.

Motion small and slow:—	Motion small, but distinct:—
$T = 1.01$ sec., $2a = 0.026$ mm.	$T = 0.72$ sec., $2a = 0.013$ mm.
	$T = 1.28$,, , $2a = 0.015$,,

(ii). 63 sec.

Motion was well-defined in both components, but more active in the transverse than in the longitudinal direction. The first vibration was entirely transverse and composed of the two displacements: 1st, 0.013 mm. toward S. 5°W.; 2nd, 0.011 mm. toward N.5°E. The next displace-

ment was 0.023 mm. toward S.36°W. The 2nd displacement of the 4th (transverse) vibration, occurring 10.4 sec. after the start, was the greatest transverse motion, of $2a=0.041$ mm. This combined to the outward (longit.) displacement of 0.024 mm. gives the resultant of 0.047 mm. toward N.22°W.

(iii), Longit. Motion Stage: Duration = 8.3 sec.

Motion regular:	Motion irregular and slow:
$T=0.83$ sec.	$T=1.32$ sec.; $T=0.52$ sec.

1st Displacement 0.035 mm. toward N.38°W.
2nd „ 0.038 „ . „ S.62°E.

The 1st displt. of the last vibration, occurring 20.8 sec. after the start, was the 2nd max. in this stage: $2a=0.029$ mm. toward S.74°E.

(iv) Last 11.8 sec.: Motion small and uniform.

$T=1.10$ sec., $2a=0.017$ mm.	$T=1.57$ sec., $2a=0.012$ mm.
	$T=0.78$ „ , $2a=0.012$ „

90. *Duration of the preliminary portion.* The duration of the introductory small motion in the diagrams of the different after-eruptions was as follows:—

Longitudinal Component. sec.		Transverse Component. sec.	
1.9		2.8	
2.5		3.0	
2.5		3.5	
2.8		3.6	
3.0	Mean,	3.8	Mean,
3.2	**3.6** sec.	4.0	**4.8** sec.
3.6		4.1	
4.0		4.3	
4.1		5.5	
5.5		5.7	
6.5		6.3	
		10.7	

The mean duration of the preliminary portion (=3.6 sec.) in the longitudinal component was about 2.0 sec. longer than the duration of the ordinary *preliminary tremor* (=1.6 sec.) corresponding to the distance of 11.8 km. between the place of observation and the craterlet No. 2 on the eastern, or Nabe-yama, side of Sakura-jima, which was most active in the days in question. This time difference may be assumed to indicate the duration of the preparatory stage of the after-eruptions. In the transverse component, the mean duration of the preliminary portion was 4.8 sec., being 1.2 sec. longer than in the longitudinal component.

91. *Range of motion.* The maximum range of motion, or double amplitude=$2a$, in either the longitudinal or the transverse component of the after-eruption movements on the successive days was as follows:—

Date.	Absolute maximum, $2a$
Jan. 16th	0.054 mm.
17th	0.048
18th	0.062
19th	0.055
21st	0.046
22nd	0.055
23rd—24th	0.029
25th—26th	0.034
29th	0.032

Thus, between the 16th and the 22nd the max. $2a$ was nearly constant and approximately equal to 0.05 mm. Between the 23rd and the 29th, it was smaller and about 0.03 mm.

92. *Difference in times of arrival of longitudinal and transverse vibrations.* Distinct motion in the transverse component occurred, on the average, 3.9 sec. (=τ) later than that in the longitudinal component, as follows:—

τ = 2.5 sec.	3.5 sec.
2.6	4.0
2.6	4.5
2.7	4.8
2.8	4.9
3.0	5.0
3.4	6.2
	6.5
	3.9 sec.

93. ***Time of occurrence of maximum movements.*** In the earthquake motion due to an after-eruption observed in Kagoshima, the principal values of the average time interval between the com-

TABLE XIX. TROMOMETER OBSERVATION IN KAGOSHIMA: TIME INTERVAL BETWEEN THE COMMENCEMENT AND THE OCCURRENCE OF THE MAXIMUM VIBRATION OR THE MOST ACTIVE PORTION OF THE EARTHQUAKE MOTION DUE TO THE AFTER-ERUPTIONS.

Longitudinal Component.				Transverse Component.			
sec.		sec.		sec.		sec.	
5.4		13.8		8.4		6.0	Mean, 6.2
6.3		14.2		8.7		6.3	
6.4		15.2		9.7			
7.0		15.4	Mean, 15.8	10.1		13.0	
7.1		16.4		10.4		13.8	Mean, 13.8
8.0	Mean, 8.2	16 5		10.5	Mean, 11.0	14.7	
8.5		17.5		10.5			
9.0		17.5		10.6			
9.4		20.3		10.9			
9.9		20.8	Mean, 21	11.2			
10.7		21.4		11.3			
10.9		21.4		11.6			

mencement and the maximum vibration or the most active portion, were, according to Table XIX, as follows:—

Longit. Compt., ... 8.2 sec.; 15.8 sec.
Transv. Compt., ... 11.0 „

Thus the 1st maximum motion occurred generally 11.0–8.2=2.8 sec. earlier in the longitudinal than in the transverse component. In the longitudinal component, the 1st maximum occurring 8.2 sec. after the commencement was often followed by a 2nd maximum about 8 sec. later on.

94. *Direction of motion.* The 1st distinct displacement in the earthquake motion due to the Sakura-jima after-eruptions was directed mostly toward to, or away from, the source of disturbance. Thus, of the 20 cases examined, the direction of the initial motion was as follows:—

Toward the source of disturbance, ... 5 cases;
Away from „ „ , ... 11 „ ;
Toward N. 77° E.; S. 47° E.; S. 70° W.; S. 48° E., ...each, 1 case.

It is possible that, in some instances, the initial displacement was obliterated by the small tremors of the ground existing more or less in the days subsequent to the commencement of the eruption.

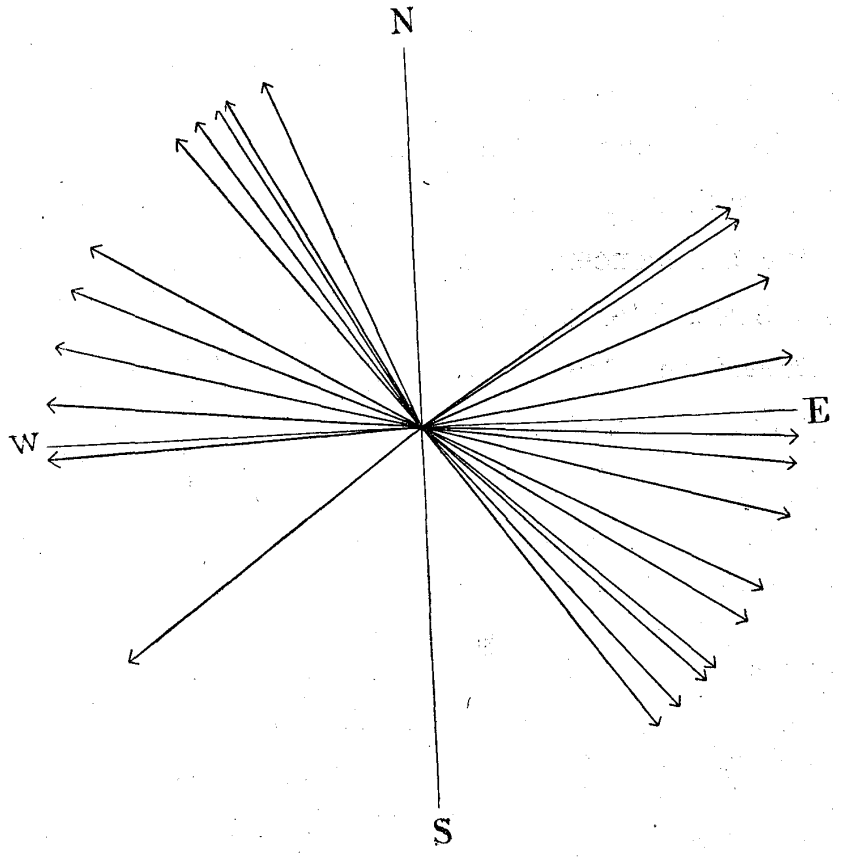
The mean directions of the maximum displacements in the principal portion were, according to Table XX, as follows:—

Longitudinal Component, ...N. 70° W.—S. 70° E.
Transverse „ , ...N. 10° E.—S. 10° W.

These directions are approximately parallel and normal to the straight line connecting the craterlets on the two flanks of the volcano.

Fig. 22. Tromometer Observation in Kagoshima of the Sakura-jima After-eruptions: Direction of the Maximum Vibration.

(Different After-eruptions taken together)



35. ***Period of vibration.*** Tables XXI and XXII give lists of the vibration periods in the earthquake motion caused by the different after-eruptions. The mean values of the periods most frequently occurring in the maximum phase of the longitudinal component were $p_1=1.09$ sec. and $p_2=2.22$ sec. The period p_1, which is equal to $\frac{1}{2}\times p_2$, was often found also in the parts preceding and following the maximum phase of the longitudinal component and in the maximum phase of the transverse component. Other periods frequently occurring in the latter motion were 0.71 sec. and 1.39 to 1.7 sec.

TABLE XX. TROMOMETER OBSERVATION OF THE SAKURA-JIMA AFTER-ERUPTIONS IN KAGOSHIMA, JAN. 16TH—FEB. 8TH, 1914: DIRECTION OF THE MAXIMUM MOVEMENTS IN THE PRINCIPAL PORTION.

Longitudinal Motion.		Transverse Motion.	
N. 22° W.	S. 36° E.	N. 5° E.	S. 5° W.
N 28°½W.	S. 40° E.	N. 8° E.	S. 8. W.
N. 30° W.	S. 4[illegible]° E.	N. 8° E.	S 8° W.
N. 34° W.	S. 48°½E.		S. 8° W.
N. 38° W.	S. 57° E.		S. 8° W.
N. 59° W.	S. 62° E.		S. 36° W.
N. 66° W.	S. 74° E.	(ii) **N. 10°E.—S. 10°W.**	
N. 75° W.	S. 82° E.		
N. 82° W.	S. 86° E.		
W.	E.		
S. 88° W.	N. 82° E.		
S. 55° W.	N. 70° E.		
	N. 60° E.		
	N. 58° E.		
(i) **N. 70°W.—S. 70°E.**			

	Longit. Compt.			Transv. Compt.		
	sec.	sec.	sec.	sec.	sec.	sec.
Max. phase.....	**1.09** ;	1.55 ;	**2.22**	**1.00** ;	**1.7** ;	2.4
Parts preceding and following the max. phase,..	**0.99** ;	1.58 ;	2.4	**0.71** ;	**1.39** ;	2.3

(The frequently occurring periods are printed in thick characters.)

Comparison with the Asama-yama and the Usu-san observations. The mean values of the periods occurring in the earthquake motion caused by the recent Asama-yama eruptions tromometrically observed at several observing stations on the mountain slope and base, at the distance of 2.3 to 6.35 km. from the centre of the crater, were as follows*:—

* See the Bulletin, Vol. VII, No. 1.

TABLE XXI. AFTER-ERUPTIONS OBSERVED IN KAGOSHIMA: PERIOD OF VIBRATION.

(Directly measured from the original tromometer diagrams.)

Longitudinal Component.			Transverse Component.		
Max. Phase.		Parts preceding and following the Max. Phase.	Max. Phase.		Parts preceding and following the Max. Phase.
0.70 sec.	1.52 sec.	0.60 sec.	0.57 sec.	1.35 sec.	0.44 sec.
0.77	1.57	0.78	0.58	1.40	0.61
0.85	1.55	0.80	0.66	1.40	0.66
0.90		0.90	0.67	1.56	0.73
0.90	1.90	0.94	0.68	1.60	0.73
0.90	1.90	1.20	0.70	1.70	0.73
0.91	2.05	1.25	0.73	1.77	0.88
0.91	2.10	0.92	0.75	1.80	0.68
0.92	2.40		0.77	1.80	
0.94	2.60	2.50	0.80	1.80	1.27
0.97	2.60	2.60	0.80	1.90	1.40
1.02	2.22	2.55	0.83	1.95	1.3
1.03			0.86	2.00	
1.03			0.86	1.7	2.1
1.03			0.88		2.3
1.03			0.88	2.24	2.4
1.04			0.89	2.50	2.3
1.04			0.90	2.60	
1.04			0.91	2.4	
1.07			0.91		
1.10			0.91		
1.11			0.92		
1.13			0.98		
1.16			1.00		
1.16			1.00		
1.20			1.02		
1.20			1.03		
1.24			1.10		
1.25			1.10		
1.26			1.14		
1.26			1.15		
1.28			1.18		
1.30			1.20		
1.33			1.20		
1.06			1.21		
			1.24		
			0.92		

(a) **4.9** sec.
(b) **2.3** „
(c) **1.25**
(d) **0.85** sec.
(e) 0.37 „

Of the five groups the most frequently occurring period were (d) and (c), and then (b). Again, the mean values of the periods existing in the micro-tremor motion observed at the time of the Usu-san eruption, July–Aug., 1910, in the immediate vicinity of the craterlets, were four-fold as follows* :—

(b′) **2.14** sec.
(c′) **1.59** „
(d′) **1.08** sec.
(e′) **0.53** „

TABLE XXII. AFTER-ERUPTIONS OBSERVED IN KAGOSHIMA: PERIOD OF VIBRATION.

(Measured from the photographic enlargements)

Longitudinal Component.			Transverse Component.		
Max. Phase.	Parts preceding and following the Max. Phase.		Max. Phase.	Parts preceding and following the Max. Phase.	
0.83 sec.	0.89 sec.	1.58 sec.	0.96 sec.	0.52 sec.	1.11 sec.
1.13	0.93		1.10	0.72	1.19
1.20	0.93	2.15	1.10	0.74	1.28
1.20	1.01	2.24	1.14	0.74	1.36
1.24	1.01	2.2	1.08	0.76	1.49
1.12	1.01			0.78	1.59
	1.05		1.64	0.78	1.70
	1.06		2.1	0.84	1.39
	1.10		1.9	0.90	
	1.13			0.75	2.10
	1.15				2.35
	1.32				2.2
	1.05				

* See the Bulletin, Vol. V, No. 1.

b′, c′, d′, and e′ are not widely different respectively from the periods b, c, d, and e, characterizing the Asama-yama eruptions.

The periods prevailing in the motion of the Sakura-jima after-eruptions observed in Kagoshima were approximately equal to those found at the Asama-yama and Usu-san. In the case of the observations at the two latter places, the vibration periods in the eruptive earthquakes and in the volcanic micro-tremors were found to be essentially identical with the slower periods existing in the motion of ordinary earthquakes. A similar relation seems to exist also in the Kagoshima observations.

CHAPTER VI. TROMOMETER OBSERVATION AT FRUSATO OF THE SAKURA-JIMA AFTER-ERUPTIONS.

96. ***Tromometer observation at Frusato.*** The portable horizontal pendulum tromometer, of the pointer magnification =200, used in Kagoshima since Jan. 16th, 1914, (§ 30), was taken on Feb. 9th to Sakura-jima and set up at the village of Frusato, 3.8 km. to the S. 45° W. from the centre of the craterlet-zone on the S.E. side of the volcano. The two horizontal pointers of the tromometer were oriented so as to register respectively the motion radial and the motion transverse to the mean origin of the disturbance; the proper pendulum period being 4.5 sec. for each component.

The first series of the tromometer observation at Frusato extended for 112 days from Feb. 9th to May 31st, 1914. The lower craterlets on the S.E., or Nabe-yama, side maintained active outbursts for the several succeeding months; causing in the Autumn next, amongst the others, a serious damage to the rice crop in the vicinity of Kagoshima. At the request of the governor of the