23. *Recent Activities of Volcano Usu (IV). Earthquakes Followed by the Birth and Development of the Lava Dome.*

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(Read Dec. 20, 1949.—Received Nov. 30, 1949.)

Paroxysmal eruption came to an end almost at the later part of October, 1944, when numerous earthquakes of another new type were recorded by the seismograph and lasted till the formation of the dome was completed. The developments of seismic activity are shown in Tables I, II by means of the daily frequency of earthquakes which were recorded by seismograph at Tōya Hot Spring covering the whole period of the paroxysmal eruptions, and birth and development of the lava dome.

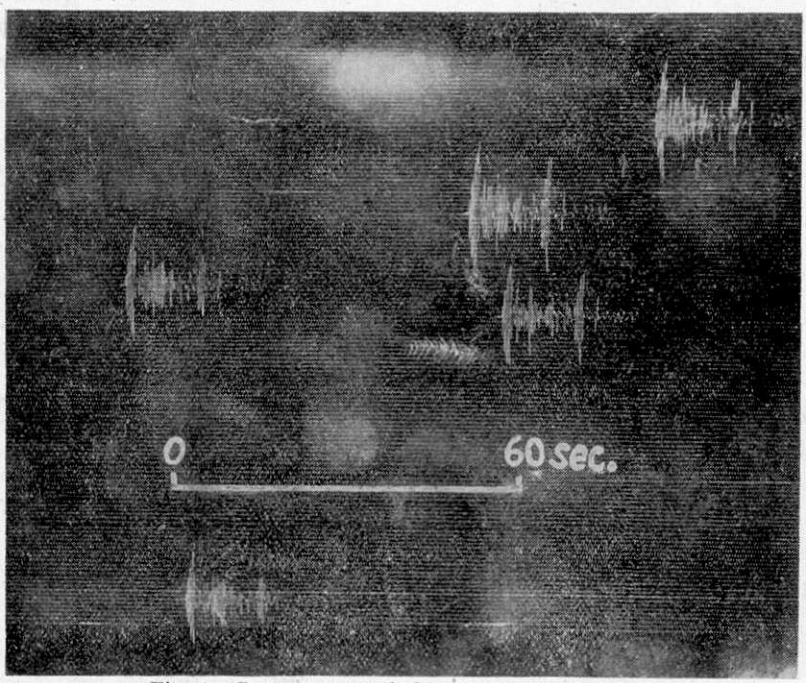

Fig. 1. Seismograms of the *C* type earthquakes.

But the earthquakes, which occurred in the various stages of the recent eruption, were entirely different in their forms of earthquake-motions.

According to the seismograms obtained at Tōya H. S., the earthquakes during this period have noticeable features in the form of earthquake motions, being very much different from those of the former two types, described in the previous paper. For convenience' sake, this type of earthquakes will be here called the *C* type. The *C* type is manifestly characterized not only by the stage of extrusion of lava, but also by the particular features, of which the forms and phases of the seismic waves and their magnitude are considerably similar to each other as is shown in Fig. 1.

In order to make clear the similarity of the *C* type earthquakes, the following investigations were made on the basis of the seismograms. The seismic waves of a seismogram of the *C* type were numbered one by one from its head to tail, as is seen in Fig. 2, and then the numbered waves were measured with respect to their periods, T_1, T_2, T_3, ...T_n together with their amplitudes, A_1, A_2, A_3, ...A_n. The procedures were carried out in regard to five seismograms (I, II, III, IV, V), which were chosen at random in many numbers of seismograms.

Series of vibration periods and amplitudes of the five earthquakes obtained in this manner, are illustrated in Fig. 3 and Fig. 4, taking periods (T_n) and amplitudes (A_n) in ordinate and the number of waves in abscissa.

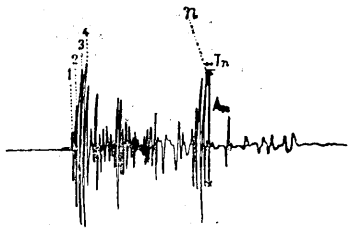

Fig. 2. A seismogram of the *C* type earthquakes.

In addition to these diagrams, series of periods and amplitudes, are compared with respect to periods, T_n and T_n', and amplitudes A_n and A_n', respectively. (Fig. 5).

It is, in fact, wonderful that the *C* type earthquakes resemble with another in full detail as if they were copies of the same earthquake.

It will be reasonable to consider that the marvellous similarity of earth-

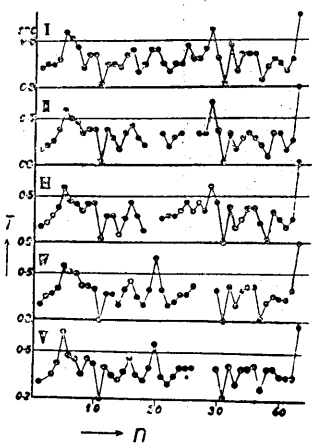

Fig. 3. Similarity of earthquake-motions of the *C* type earthquakes.
n; seismic wave numbered from the head of seismogram.
T; period of the corresponding waves.

quake-motions is caused by repetition of the same mechanism of production of the seismic waves at the same location of hypocentre and by the mode of propagation passing through the identical path from the origin to the station.

Judging from the general rule in natural phenomena that a complex phenomenon is hardly repeated in a perfectly similar manner, we may believe, as T. Matuzawa[1] remarked with respect to the similarity of earthquakes of the same origin, that the dynamical mechanism producing the seismic waves of the *C* type at the hypocentre must be so simple as to be easily repeated.

However, the seismograms of the *C* type earthquakes recorded at Tōya H. S., 5 km distant from their epicentre show rather complex in com-

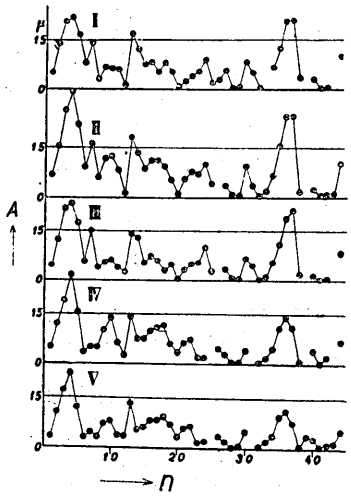

Fig. 4. Similarity of earthquake motions of the *C* type earthquakes.
n; seismic waves numbered from the head of seismogram.
A; amplitude of the corresponding waves.

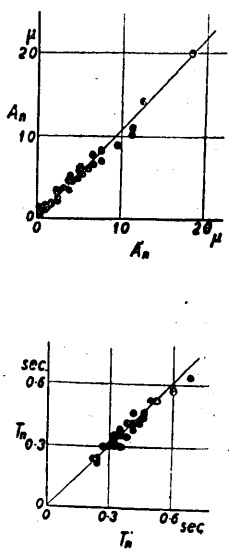

Fig. 5. Comparison of periods (Tn, Tn') and amplitudes (An, An') of corresponding waves of two *C* type earthquakes.

parison with the *A* type ones. As already mentioned, the complexity of this kind depends on the more complicated formations of the upper part of the volcano than those of the deeper formations.

On the other hand, the hypocentres of the *B* type earthquakes which occurred during the stage of the paroxysmal eruption were estimated within the semi-spherical domain of 1 km in diameter, including the earth'

1) T. Matuzawa, *Zisin* (*Earthquake*), (1932).

surface of the rising area. According to examinations of the *B* type seismograms, their earthquake-motions are similar to some extent, though not so evident, to those of the *C* type. Moreover, the *C* type earthquakes have intermediate characters between the *A* and *B* types earthquakes in the mean periods of earthquake-motions as well as in the forms of the seismic waves.

From these various facts described in the preceeding and present reports, we can draw the following conclusion——the *C* type earthquakes probably occurred within a more limited domain than that of the *B* type, at the depth of nearly 0.5–1.0 km below the newly forming dome. Accordingly, it seems that the *C* type earthquakes have close relation to the enormous forces which acted on the subterranean base of the dome, namely a lower end of the conduit.

Finally, we may deal with the problem whether earthquakes of tectonic origin and those of volcanic origin have their respective characteristics or not. It is evident that volcanic earthquakes have been defined chiefly by the geographical positions of their epicentres, and not by the characters of their earthquake-motions or their mechanism of production of the seismic waves. The problem is now treated briefly taking into account the properties of these two kinds of earthquake motions, we can not find, as seen in Fig. 6 in the preceeding report, any difference between the *A* type earthquakes observed at the Usu volcano and the after-shocks of tectonic earthquakes. However, the earthquakes such as the *B* and *C* types observed at the recent eruption, have not been recorded at the seismic activity of tectonic origin, though at the occasion of the catastrophic earthquakes in Japan, their after-shocks were frequently observed by various seismographs in the vicinity of their epicentral area. Seeing that the *A* and *B* types earthquakes at the present Usu are characterized chiefly by the extremely shallow depth of their hypocentres, it seems that the tectonic earthquakes do not take place at such shallow depth as in the case of the recent activity of Usu. On the other hand, it must be added that earthquakes resembling the *B* type of the Usu volcano have been observed occasionally prior to and in the course of the eruptions of Asama, Kusatu-sirane and other volcanoes in Japan.

Moreover, the daily frequencies of earthquakes which were recorded at the five stations in the course of the recent eruption, were represented in Tables I and II.

The writer wishes to express his thanks to Mr. T. Utibori and to Miss T. Takahashi for their valuable assistances in seismometric observations at the Usu volcano and in the laboratory works.

Most of the expense necessitated for this research was defrayed from the funds for Scientific Research of the Department of Education.

Table I. The daily frequency of the earthquakes observed by the seismographs at the five stations during June 27—August 11, 1944.

Date		Hukaba	Sōbetu	Kami-Osaru	Tōya H. S.	Usu
June	27	—	22		2	
	28	50	38	3	1	
	29	430	31	19	1	
	30	450	51	33	3	
July	1	445	38	35	7	
	2	48	2	3	3	
	3	10	3	8	4	
	4	5	5	8	11	
	5	0	0	2	2	
	6	0	0	3	1	
	7	10	0	2	0	
	8	82	3	2	1	
	9	190	10	11	2	
	10	350	26	33	4	
	11	166	10	22	3	—
	12	530	19	31	4	4
	13	225	37	27	5	8
	14	228	18	7	3	5
	15	140	10	4	2	2
	16	118	4	10	0	1
	17	203	7	7	2	3
	18	149	16	13	4	5
	19	149	14	13	3	0
	20	198	10	19	3	1
	21	340	52	20	0	1
	22	340	40	15	1	3
	23	233	36	11	2	3
	24	885	32	10	1	3
	25	675	17	3	1	0
	26	893	15	9	2	1
	27	785	36	13	1	0
	28	690	41	12	0	0
	29	587	55	14	6	4
	30	630	85	12	0	0
	31	630	69	27	6	10
August	1	520	52	12	0	
	2	340	35	6	2	
	3	495	37	19	7	
	4	420	82	10	7	
	5	430	27	35	37	
	6	800	92	48	22	
	7	135	84	49	22	
	8	125	82	33	40	
	9		66	22	28	
	10		68	19	23	
	11		17		20	

Table II. The daily frequency of the earthquakes observed by the seismograph at Tōya Hot Spring during August 1, 1944—March 12, 1945.

Date	August	September	October	November	December	January	February	March
1	0	8	11	16	50	35	26	21
2	2	4	5	15	55	39	27	23
3	7	4	30	9	47	34	24	31
4	7	5	18	2	51	33	28	21
5	37	3	25	—	54	30	25	25
6	22	10	25	10	57	34	29	22
7	22	13	28	11	30	28	20	18
8	40	12	4	8	7	10	25	23
9	28	9	0	5	48	—	19	17
10	23	6	12	4	43	18	8	22
11	20	4	27	3	51	34	30	21
12	31	2	31	9	50	30	17	18
13	18	7	29	14	57	44	23	
14	9	7	35	27	45	40	20	
15	13	10	37	20	53	47	31	
16	9	13	46	21	47	37	24	
17	3	10	42	6	48	38	15	
18	10	8	48	—	51	27	27	
19	6	4	56	16	39	15	27	
20	2	4	45	18	47	33	27	
21	11	8	42	26	43	37	31	
22	15	5	37	22	46	30	28	
23	11	7	31	20	52	37	31	
24	12	5	26	24	53	36	25	
25	9	14	13	23	40	35	24	
26	10	13	19	23	38	33	27	
27	2	22	16	11	40	35	27	
28	11	12	—	24	43	31	23	
29	8	15	24	33	40	37		
30	8	11	20	36	45	33		
31	4		22		45	29		