50. Geophysical Studies of Mihara Volcano, Oosima Island. IV.

A Minor Activity of Volcano Mihara, August 11, 1938.

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1. Mihara Volcano has been calm since the great eruption during the period of 1911∼1914, as already reported by the writer[1]. Minor activities of the volcano, however, observed several times after the great eruption, the most recent being a succession of miniature eruptions that occurred on August 11, 1938, which was the severest since the outburst of September 1934. Before the volcano became active, its crater bottom was covered with a solidified lava-sheet pierced with several openings. From the midnight of August 10, new incandescent lava-flows began to spread over the bottom, until in the early morning of 11 th, the surface of the lave-flow rose to a height of 35 *m* from the bottom. Throughout this activity, gas was emitted violently once or twice every minute, simultaneously with which fragments of incandescent or solidified lava were projected. This activity reached maximum at about 6 *h* of the 11 th, which from 8 *h* began to cease down with decrease of lava-flow. At 11 *h*, the incandescent lava-flow settled down to its usual depth below the crater-bottom, solidified lava sheets still adhering to the pit-wall. The maximum height of the lava that welled up could therefore be estimated by measuring the height of the lava-sheet.

2. Although no fragments of incandescent lava that was projected during the recent activity reached as far as the pit-mouth, those of the solidified lava were thrown out of the pit and fell around the pit-mouth. The fragments are porous, black basalt of diameters from 2·5 to 6·0 *cm*. These projected fragments are "Miharaite" as determined petrologically by S. Tsuboi[2]. They were in an amorphous state and very porous, the mean density being 0·5∼0·7. Several of these specimens are shown in Fig. 1, and the distribution of the projected fragments in Fig. 2

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[1] R. TAKAHASI and T. NAGATA, *Bull. Earthq. Res. Inst.*, **15** (1937), 441.

[2] S. TSUBOI, *Journ. Sci. Coll. Tokyo Imp. Univ.*, **43**.

(plate). It will be seen from the figure that more fragments were projected on the S–W side of the pit than on the other sides, which fact is probably due to the effect of the N–E wind that had a velocity of 10 m/sec. throughout the period of activity. Hence, the outer-boundary of the area on which the fragments were distributed, were there no wind, would have been as that shown with dotted line in Fig. 2.

From the distribution of these fragments it is possible to estimate the initial velocity of the projection and the gas-pressure of the present eruption. The relation between bomb-distribution and their initial velocities that have been studied by a number of investigator[3] do not seem to apply to the present case unless with certain modifications. In the present case, both the effects of air-viscosity and of the shape of the pit must be taken into account. We shall now calculate this relation, taking the two effects into account.

For simplicity of mathematical treatment, we take the mean shape of the fragment as a sphere. If the x–axis be drawn horizontally, and the z–axis upward, the equation of motion would be approximately

$$\left.\begin{aligned} &M\frac{d^2x}{dt^2}+K\rho_0 d^2\left(\frac{dx}{dt}\right)^2=0, \\ &M\frac{d^2z}{dt^2}+\delta K\rho_0 d^2\left(\frac{dz}{dt}\right)^2+Mg=0, \end{aligned}\right\} \qquad (1)$$

where $\delta=1$ when $\frac{dz}{dt}\geqq 0$ and $\delta=-1$ when $\frac{dz}{dt}\leqq 0$,

M = Mass of the fragment,
d = Mean diameter of the fragment,
g = Gravity,
ρ_0 = Density of air,
ρ' = Mean density of the fragment,
K = Coefficient of air-resistance determined empirically.

As mentioned in Matuzawa's[4] paper, K is a constant, 0·12, provided Reynolds's number is $10^3\sim10^5$.

The solutions of the equation which satisfy the initial conditions

$$\left.\begin{aligned} &x=z=0, \\ &\frac{dx}{dt}=V_0\cos\theta, \quad \frac{dz}{dt}=V_0\sin\theta, \end{aligned}\right\} \text{ when } t=0,$$

and the condition of continuity

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[3] T. MATUZAWA, *Bull. Earthq. Res. Inst.*, **11** (1933), 329.
T. FUKUTOMI, *Zisin.* (*in Japanese.*), **1** (1929), 852.
T. NOMITSU and M. NAMBA, *Mem. Col. Sci., Kyoto Imp. Univ., A.* **15** (1932), 215.

[4] T. MATUZAWA, *loc. cit.*

$$z_+ = z_- \quad \text{when} \quad \frac{dz_+}{dt} = \frac{dz_-}{dt} = 0,$$

are

$$\left.\begin{aligned} x &= \frac{1}{\lambda}\log\left(\lambda t + \frac{1}{V_0\cos\theta}\right) + \frac{1}{\lambda}\log V_0\cos\theta, \\ z_- &= -\frac{1}{\lambda}\log\cosh\left\{\sqrt{\lambda g}\,t + \cot^{-1}\left(\sqrt{\frac{\lambda}{g}}V_0\sin\theta\right) - \frac{\pi}{2}\right\} \\ &\quad + \frac{1}{\lambda}\log\sqrt{1+\frac{\lambda}{g}V_0^2\sin^2\theta}, \\ z_+ &= \frac{1}{\lambda}\log\sin\left\{\sqrt{\lambda g}\,t + \cot^{-1}\left(\sqrt{\frac{\lambda}{g}}V_0\sin\theta\right)\right\} \\ &\quad + \frac{1}{\lambda}\log\sqrt{1+\frac{\lambda}{g}V_0^2\sin^2\theta}, \end{aligned}\right\} \tag{2}$$

where

$$\lambda = \frac{K\rho_0 d^2}{M} = \frac{6K\rho_0}{\pi d\rho'},$$

and z_+, z_- denote respectively the value of the z-ordinate of the locus in the upward and downward courses of the projectile.

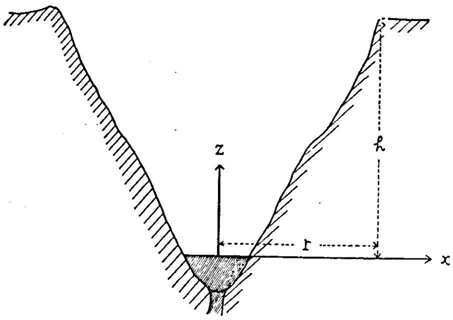

Fig. 3.

If the pit is assumed to be of the shape shown in vertical section in Fig. 3, the fragments that were projected on the old-crater bottom must have had the initial velocity and the angle of projection as determined by the relation

$$\left.\begin{aligned} z_+ &\geqq h \quad \text{when } x=r, \quad \text{if } x_0 \geqq r, \\ z_- &\geqq h \quad \text{when } x=r, \quad \text{if } x_0 \leqq r, \end{aligned}\right\} \tag{3}$$

where x_0 is the value of x when $\frac{dz}{dt}=0$. These relations are expressed in our case as follows:

$$\left.\begin{aligned} &\sqrt{1+\frac{\lambda}{g}V_0^2\sin^2\theta} \geqq e^{\lambda h}\operatorname{cosec}\left\{\sqrt{\frac{g}{\lambda}}\frac{e^{\lambda r}-1}{V_0\cos\theta} + \cot^{-1}\left(\sqrt{\frac{\lambda}{g}}V_0\sin\theta\right)\right\} \\ &\qquad \text{if} \quad \sqrt{\frac{\lambda}{g}}V_0\cos\theta\left\{\frac{\pi}{2} - \cot^{-1}\left(\sqrt{\frac{\lambda}{g}}V_0\sin\theta\right)\right\} \geqq e^{\lambda r}-1, \\ &\sqrt{1+\frac{\lambda}{g}V_0^2\sin^2\theta} \geqq e^{\lambda h}\cosh\left\{\sqrt{\frac{g}{\lambda}}\frac{e^{\lambda r}-1}{V_0\cos\theta} + \cot^{-1}\left(\sqrt{\frac{\lambda}{g}}V_0\sin\theta\right) - \frac{\pi}{2}\right\} \\ &\qquad \text{if} \quad \sqrt{\frac{\lambda}{g}}V_0\cos\theta\left\{\frac{\pi}{2} - \cot^{-1}\left(\sqrt{\frac{\lambda}{g}}V_0\sin\theta\right)\right\} \leqq e^{\lambda r}-1. \end{aligned}\right\} \tag{4}$$

In the case of the present eruption, we may take

$$\rho_0=0{\cdot}00120, \qquad \rho'=0{\cdot}64, \qquad d=0{\cdot}035\,\mathrm{m}$$

and

$$r=160\,\mathrm{m}, \qquad h=220\,\mathrm{m},$$

whence we have the actual relations

$$\left.\begin{array}{l} \sqrt{1+0{\cdot}0127\,\xi^2} \geqq 15{\cdot}3\,\mathrm{cosec}\left\{\dfrac{56{\cdot}0}{\xi}\tan\theta+\cot^{-1}(0{\cdot}113\,\xi)\right\}\ , \\ \sqrt{1+0{\cdot}0127\,\xi^2} \geqq 15{\cdot}3\,\cosh\left\{\dfrac{56{\cdot}0}{\xi}\tan\theta+\cot^{-}(0{\cdot}113\,\xi)-1{\cdot}571\right\}, \end{array}\right\} \quad (5)$$

each of which corresponds respectively to the cases

$$\left.\begin{array}{l} 0{\cdot}113\xi\,\cot\theta\left\{1{\cdot}571-\cot^{-1}(0{\cdot}113\xi)\right\} \geqq 6{\cdot}32, \\ 0{\cdot}113\xi\,\cot\theta\left\{1{\cdot}571-\cot^{-1}(0{\cdot}113\xi)\right\} \leqq 6{\cdot}32, \end{array}\right\} \quad (6)$$

where $\xi\equiv V_0\sin\theta$.

These relations are shown by the graphs in Fig. 4. From this figure, we may conclude that the minimum velocity and the angle of projection with which the fragments can be thrown out on the old-crater bottom is about 135 m/sec. and 75° respectively. Moreover, if we assume that the gas-pressure p, by which the fragments were projected is given by

$$p=\frac{1}{2}\rho'\,V_0^2,$$

the least pressure by which the fragment can just be ejected from the pit is

$$p=58\ \mathrm{atm}.$$

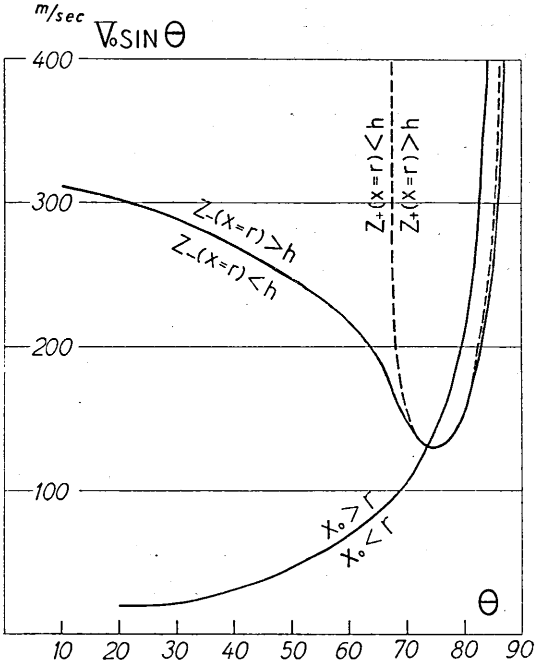

Fig. 4.

On the other hand, if we assume that the initial velocity of the projection is uniform in all directions, i.e. independent of θ, the direction of projection, the maximum horizontal distance x_m

of the fragment on plane $z=h$ (old-crater bottom) is a function of V_0 alone. Conversely, if we know the largest value of x_m, we can estimate the maximum initial velocity, that is, on the above assumption. The value of x in the case of $z_-=h$ was calculated from eq. (2), V_0 and θ in which satisfy the condition of eq. (4). The largest value of x thus obtained corresponding to each of the various values of V_0 was selected, and denoted x_m. Then the relation between V_0 and x_m in our case is expressed by the curve shown in Fig. 5. As the distance between the centre of eruption and the outer-boundary of the area where the fragments were distributed (i.e. the largest value of x_m), is about 200 m, as shown in Fig. 2, the maximum velocity in the present case is 170 m/sec., while the corresponding gas pressure is 92 atm. This value of gas-pressure is much smaller compared with those estimated by T. Matuzawa5) for the cases of the eruption of Volcano Asama and other volcanoes in Japan, where $p \fallingdotseq 230 \sim 550$ atm.

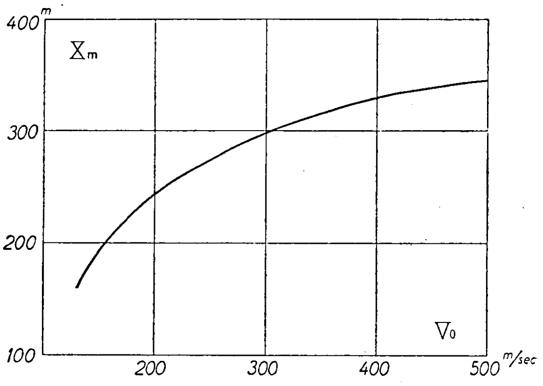

Fig. 5.

In the above calculations it was assumed that the mechanism of the projection of the fragments is such that they were given a certain initial velocity by the gas-pressure at an instant of the eruption, and their subsequent motions subjected only to the forces of gravity and the resistance of air, which is standstill. Other forces, such as the pressure of the ascending gas emitted from the crater-bottom and the convective motion of the air in the pit etc might also affect the motion of the fragments. While in the present case, these effects would not be negligibly small, they may be not so large as to change the order of the initial velocity of the projection obtained by the above calculations. In the case of violent eruptions of Volcano Asama that these forces extremely affect the motion of the fragments is conceivable. Seeing that in the present eruption of Volcano Mihara the emitted gas began to diffuse in all directions soon after the emission and began to make a convective motion before the gas-front reached the height of only 50 m from the bottom, while in the cases of violent eruptions of Volcano

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5) T. MATUZAWA, *loc. cit.*

Asama the emitted gas ascends to the height of several thousand meters making a shape of a column, we may conclude that the pressure of the ascending gas would be large in the latter but very small in the former.

3. The temperature in the fumaroles on the old-crater bottom has been measured once or twice a week since September 1937. R. Takahasi and the writer[6] reported that when gas is emitted more or less violently, the temperature varies by two or three degrees, that is, when the volcano is comparatively active, it fluctuates in the range between 66°C and 69°C, whereas on calm days it is constantly 67°C. The observed values of the temperature both before and after the recent eruption are shown in Fig. 6, where we notice that the temperature has changed in association with the present activity, that is, it started to fall at the beginning of the activity until it reached 58°C, a minimum, after which it is now rising back to its normal value. The mechanism responsible for the temperature-change is not at present clear, although several can be assumed.

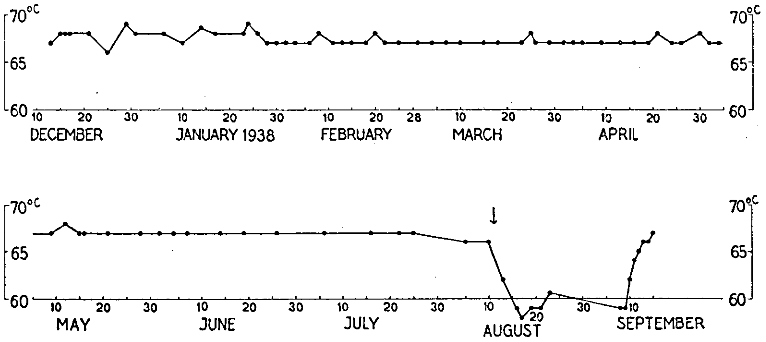

Fig. 6. Change in Temperature of Humarole.

4. The present activity not being violent, there were no marked change in volcanic tremors, earth–tilts, or earth-currents, notwithstanding the continuous observations that were being made at the foot of Mt. Mihara and on its somma.

In short the activity of August 11 was the severest during the last four years, yet it was very quiet compared with the frequeut eruptions of Volcano Asama and other volcanoes in Japan.

In conclusion, the writer wishes to record his indebtedness to Prof. M. Ishimoto, the director of the Institute, for his encouragement, and

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6) R. Takahasi and T. Nagata, *Read at the annual meeting of Physico Math. Soc. Japan* (Apr. 1938).

to Dr. C. Tsuboi, Dr. N. Miyabe, and Dr. K. Kanai for their valuable advices. His hearty thanks are also due to the Hattori-Hôkô-Kai, by the aid of whose grant these geophysical studies of Volcano Mihara were carried out.

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50. 三原火山の地球物理學的研究

昭和13年8月11日の小活動

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1. 昭和13年8月10日深更より翌11日早朝にかけて三原火山は小活動を爲した. その間直徑數糎の熔岩片を多數に噴出したがその分布から爆發の壓力を推定した結果 60〜90 氣壓程度と思はれる.

2. 噴氣孔の蒸氣溫度が今度の噴火前後から著しい低下を示した他には，火山微動，傾斜，地電流，火山地震の發生等には著しい變化が見られなかつた.

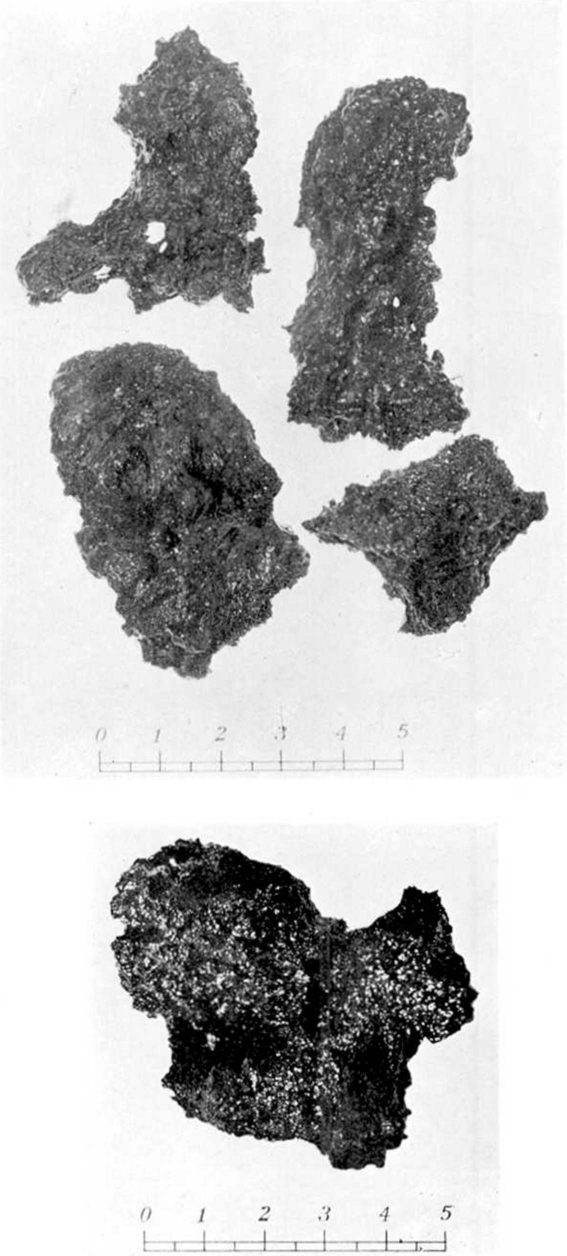

Fig. 1. The Fragments of Lava,
projected Aug. 11, 1938.

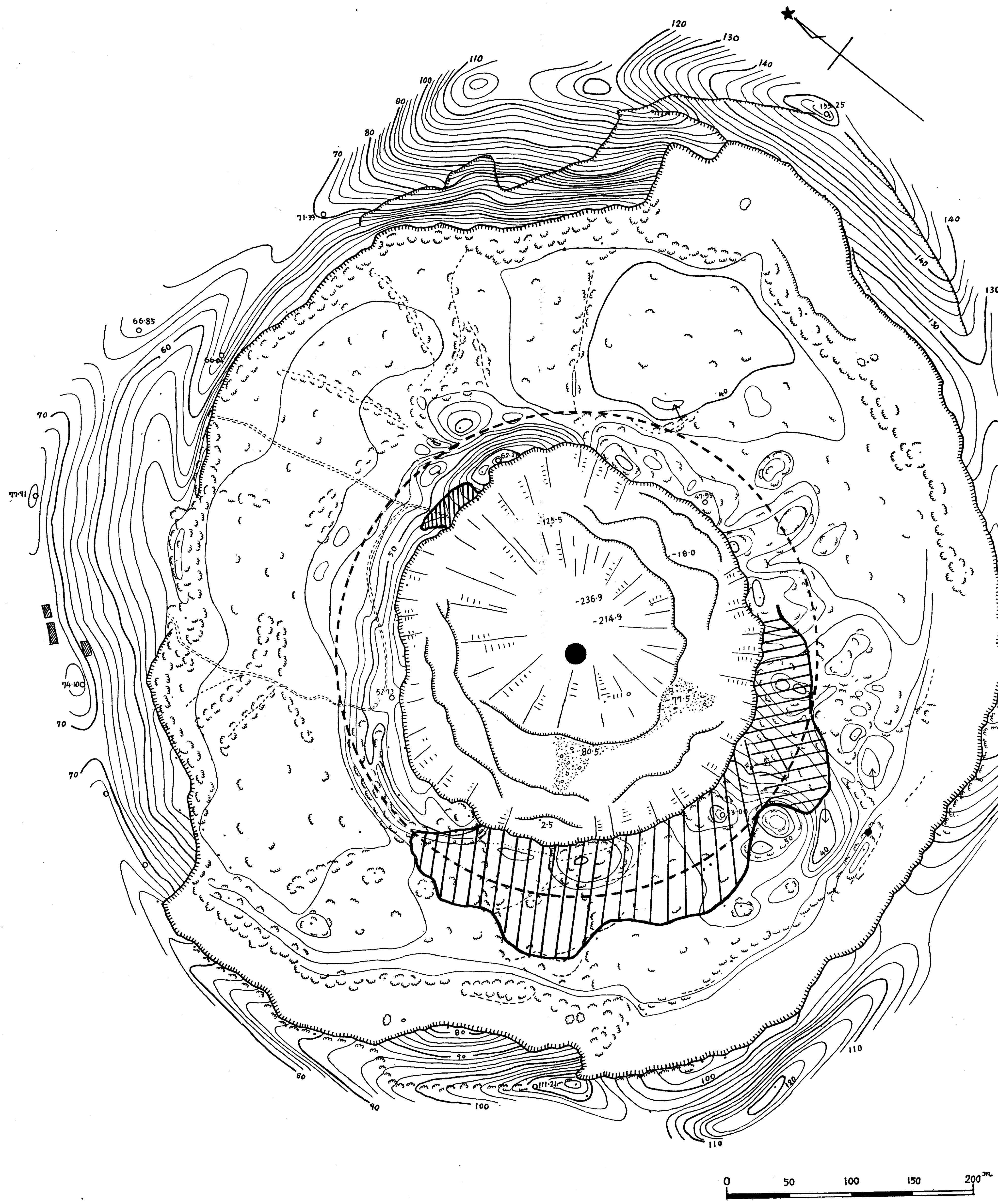

Fig. 2. The distribution of the projected fragments in the minor eruptions of Volcano Mihara, August 11, 1938.