
To explain the mechanism of volcanic eruption, whether lunar or terrestrial, we may consider the volcano as a two-phase system consisting of the solid particles and a gas. We analyze the one-dimensional flow due to the eruption of such a two-phase system. From the field observation (G. Fielder, 1971) and some preliminary theoretical calculations (T.R. McGetchin and G.W. Ullrich, 1973), the general flow field of a volcano may be divided into two regions: The lower part, region I, starts from a great depth in the planet, a mixture of molten rock and the gas flows upward in a duct of almost constant cross-sectional area under very high pressure. In this region, the mixture of molten rock and the gas behaves like an incompressible fluid. The flow field is simple and should not deviate much from the simple analysis by T.R. McGetchin and G.W. Ullrich (1973). We shall not discuss it. When the flow is near the surface of the planet with \( x > -H_0 \) where \( x \) is the vertical coordinate, the area of the duct increases and the mixture expands as it flows upward. We call this as region II.

We study the essential features of region II of lunar and terrestrial volcanic flows, especially for similar flow patterns of a terrestrial volcanic flow with a corresponding lunar volcanic flow.

We consider the equilibrium flow (S.I. Pai, 1977) of the mixture of the molten rock and the gas in region II. From the fundamental equations of the mixture of solid particles and a gas of equilibrium flow of a volcano in a planet, we find that there are four non-dimensional parameters, i.e., (i) the initial Mach number \( M_0 \), (ii) initial Froude number \( F_0 \), (iii) initial density ratio \( G \) of the density of solid particles to that of the gas and (iv) mass concentration of the solid particles in the mixture \( k_p \).

We compare a terrestrial volcanic flow with a similar lunar volcanic flow. For the similitude of these two volcanic flows, we should have both geometrical similitude and dynamical similitude (I.S. Sedov, 1959). By geometrical similitude, we mean that there is a linear scaling of region II of the terrestrial and the lunar volcanoes. We should compare these flow fields with the same non-dimensional initial area \( \tilde{A}_0 \) and the same slope of the non-dimensional variation of the cross-sectional area in region II. By dynamical similitude, we mean that the most important non-dimensional parameters, i.e., \( M_0, F_0, G \) and \( k_p \) for the similar terrestrial and lunar volcanic flows should be equal. We assume that the initial temperature, \( T_0 = 1000^\circ \mathrm{C} \), is the same in these two similar terrestrial and lunar volcanic flows. We also assume that in the terrestrial volcanic flow, the principal gas is steam while that in the lunar volcano is hydrogen. By dynamical similitude, we find that (i) the initial value of velocity in the lunar case should be 3.126 times that of the terrestrial case; (ii) the initial pressure of the lunar case is 9 times that of the terrestrial case and (iii) the characteristic length of the lunar case is about 60 times that of the terrestrial cases. From these characteristic lengths and geometrical similitude, we determine the corresponding ratio of the exit area of the volcano \( A_0 \) to the initial area \( A_0 \) for various shapes. These ratios \( A_0/A_0 \) for the lunar cases are about 30 to 50 times that.
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of the corresponding terrestrial cases.

We calculate the equilibrium inviscid flow of similar cases of lunar and terrestrial volcanoes for two conditions: (i) isothermal case and (ii) adiabatic case for various $A_s/A_o$ and $k_p$ with $M = 1.0$. The main results are as follows:

(i) In the terrestrial cases, the exit velocity from the volcano is supersonic but its value is much smaller than the terrestrial escape velocity; but in the lunar cases, the exit velocity from the volcano may be higher than the lunar escape velocity when the mass concentration of the rock is less than $k_p = 0.8$ (see Fig. 1). (ii) In the adiabatic case, the lunar volcanic flow may reach its maximum possible velocity before the exit and the volcanic flow will leave the volcano as a jet stream with velocity greater than the lunar escape velocity. Thus the flow field agrees with the assumed flow pattern of a stream of tektites coming from the moon (D.R. Chapman and H.K. Larson, 1963). (iii) When $k_p$ is large, and $(A_s/A_o)$ is small, the temperature in the terrestrial cases is quite close to its initial value. When $k_p$ is small, the initial drop of the temperature in both the terrestrial and the lunar cases is large and in the major portion of the duct, the temperature is almost constant but is less than the initial temperature and (iv) the variations of both the velocity and the pressure in the terrestrial cases are gradual. For the lunar case, the pressure drops very rapidly to a very low value initially and then remains almost constant for the major portion of the duct. The variation of the pressure with $k_p$ is always negligibly small.

References


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Figure 1. Comparison of the actual velocity of adiabatic similar lunar and terrestrial flows along the duct with $k_p$ as a parameter for the corresponding area ratio ($A_s/A_e$)$_e = 4$ and ($A_s/A_e$)$_m = 181$. 