Lava Flows and Forms

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ABSTRACT

Assuming that many lavas behave as very thin flows of a Newtonean viscous liquid, one can derive a non- linear partial differential equation of the parabolic type that governs the shape of the surface of such flows. Although the boundary condition at the front of the lavas still presents an unresolved problem, the resulting equation can be applied to estimating the viscosity of flowing lavas.

INTRODUCTION

The mechanism of lava flow is of both geoscientific and direct practical interest. Basaltic layers and other extrusions comprise a prominent part of exposed igneous rock and the study of the mechanism of formation of these structures is therefore important from the geological point of view. Lava flows have also interfered with human affairs and have occasionally caused damage to property. We have only to recall the destruction due to the eruption on Heimaey in Iceland in 1973. *Walker* (1973) correctly emphasizes the real social need to be able to predict the behavior of lava flows advancing on populated areas.

Any attempts at gaining a better understanding of the mechanism of lava flow will have to commence with the collection of physical data and with the development of relevant flow models. The present paper has been written for the purpose of presenting an elementary flow model which may be of some interest in the present context.

SOME CHARACTERISTICS OF LAVA FLOWS

A considerable number of geological and physical data mainly on historical lava extrusions are given by *Walker* (1973) where the factors that affect the ultimate length of lava flows are discussed at length. The author notes that while some low-viscosity lava flows have reached lengths of 100 to 200 km their thickness varies only between 2 and 30 meters. Length/thickness ratios may thus amount to as much as 10,000 and such extrusions behave as truly thin-sheet flows. According to *Hooper* (1982), some of the Columbia River basalt flows have reached lengths in excess of 500 km with an average thickness of only 30 m. Very briefly, some of the main characteristics of such lava flow-sheets can be listed as follows.

(1) Even relatively fluid lavas with viscosities in the range 10^3 to 10^6 Pas advance at a slow rate (*Walker,* 1973). Velocities range from meters to kilometers per day. The mode of such flow is obviously that of viscous creep where inertia forces can be neglected.

(2) The rheological properties of lavas are apparently complex and only poorly known. According to *Hulme* (1974) there are indications that magmas may behave as Bingham liquids, that is, possess a yield strength. At stresses above the Bingham limit, magmas probably behave as Newtonean liquids, but the viscosity is highly temperature dependent. Moreover, the temperature and chemistry of lavas may vary along the flow due to chemical reactions and outgassing.

(3) As a consequence of the temperature dependent viscosity, the heat balance of lavas is of great importance for the rheology. In particular, it is to be noted that lavas generally form a solid crust and a solid bottom layer that reduce the effective height of the liquid section.

(4) Lava flows have a free surface and their motion is therefore subject to a non-linear surface condition.

(5) The mechanical processes in the fronts of lava flows differ from the situation in the liquid interior. The solidified crust piles up at the front and forms a type of barrier or wall that has to be partially pushed ahead of the flow or under the advancing lava. This condition remains to be quantified.