The Spreading of Two-phase Viscous Gravity Currents

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Viscous gravity currents involve the spreading of viscous fluid being driven by its own weight. Its theory has numerous applications in geosciences, from small scale emplacement of lava flows or glaciers, to large scale flow of mantle plume heads, deformation of weak continental crust under its own weight and flow of ice polar caps. Gravity currents in real geological settings are, however, very complex and are comprised of a mixture of several components : lava and gas or crystals for lava flows, matrix and melt for plume heads, ice and liquid water for glaciers etc... The general equations for the spreading of a two-phase mixture composed of matrix and fluid, for which the matrix has a much higher viscosity than the fluid, are developed. A loss of fluid phase through the upper boundary of the current is considered when the density of the fluid is smaller than the density of the matrix. We consider both constant volume and constant volume rate flows.

A particular focus is given to lava flows containing a gas phase and to the effects of degassing on the spreading of the current. But results can be applied to spreading of mantle plume heads below the lithosphere, as they contain some melt. As the current spreads, its surface increases and degassing becomes easier, which, in turn, increases the density of the flow and facilitates the spreading. When the loss of fluid becomes significant, the thickness evolution diverges significantly from the single-phase evolution. It returns to it when degassing is complete. We derive the characteristic time for complete degassing of lava flows as a function of gas and lava physical properties. We also find a characteristic thickness for degassing to become significant and a characteristic radius for complete degassing. The shape of a two-phase viscous gravity current does not differ significantly from the shape of a single-phase flow.