Journal of Glaciology 2000 vol.46 N153, pages 177-187

Modelling dynamics of glaciers in volcanic craters

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Abstract

General equations of ice dynamics are re-examined, using scale analysis, in order to derive a simplified thermomechanically coupled model for ice flow and heat transfer in ice caps filling volcanic craters. Relatively large aspect ratios between crater depths and diameters, low surface temperatures and intense volcanic heating are the principal characteristics of such craters. The conventional boundary-layer (shallow-ice) approximation is revised to account for these conditions and, in addition, the variable density of the snow, firn and bubbly ice. Large crater depths and intense bottom melting result in longitudinal balance velocities, controlled by both shear and longitudinal stresses, and hence small surface slopes. In such situations ice can be assumed to be linearly viscous. A flowline model of the glacier dynamics is developed using this assumption. Explicit predictive formulas for ice-particle trajectories and age-depth relations, thus obtained, suggest that the age of ice at the bottom of glaciers in volcanic craters on Kamchatka Peninsula, Russia, may reach hundreds or thousands of years. Ice cores from these glaciers represent unique climatic and volcanic archives.