NUMERICAL SIMULATION OF LAVA FLOWS; APPLICATIONS TO THE TERRRESTRIAL PLANETS. James R. Zimbelman and Bruce A. Campbell (CEPS/NASM, Smithsonian Inst., Wash., DC 20560), Juliana Kousoum (Thom. Jefferson H.S. for Sci. and Tech., Alexandria, VA 22312), and Derrick J. Lampkin (Ohio St. Univ., Columbus, OH 43210).

Lava flows are the visible expression of the extrusion of volcanic materials on a variety of planetary surfaces. A computer program described by Ishihara et al. (1) appears to be well suited for application to different environments, and we have undertaken tests to evaluate their approach. Our results are somewhat mixed; the program does reproduce reasonable lava flow behavior in many situations, but we have encountered some conditions common to planetary environments for which the current program is inadequate. Here we present our initial efforts to identify the 'parameter space' for reasonable numerical simulations of lava flows.

The program uses the steady state solution of the Navier-Stokes' equation for a Bingham fluid with constant thickness that flows down an inclined plane. Lava motion stops when the thickness is less than the critical depth, which depends on yield strength, gravity, density, and underlying slope. Heat loss occurs solely through radiation from the flow. Limited field data for basaltic flows were used to derive expressions for yield strength and viscosity as a function of temperature. This simplified program was able to reproduce the general shape and thickness of several historic flows in Japan, all of which were emplaced on relatively large slopes (generally > 3°).

The program provided in the Ishihara paper was modified to accommodate current computer capabilities, and it ran successfully when error traps were added to exclude calculations near zero slope. Reasonable flows were produced for slopes >1°. The Ishihara radiation algorithm produces very little cooling of the flows, so that they tend to be volume-limited by the lava supply rate. Several simulations were run on inclined planes to investigate the effect of varying slope, gravity, eruption temperature, and effusion rate while keeping all other parameters constant. Resulting flows varied considerably in shape and thickness, and the aspect ratio (length/width) should prove to be a useful quantity for comparison to real flows.

The program did not run satisfactorily on DEMs derived from contour maps if these topographic models contained significant areas of zero slope. Modifications were made to allow for pressure-driven flow on very shallow slopes, with the constraint that the flow front was not allowed to exceed the angle of repose, and for floating-point topographic arrays (Fig. 1). More modifications will certainly be needed to address other limitations that affect the modeling of flowing lava (see 2).

With proper awareness of the model limitations, simulations should be applicable to planetary environments. Earth: The current program is best suited for flow emplacement on surfaces sloping >1°, such as flows on the flanks of shield volcanoes like Kilauea. Modeling the well-documented Puu Oo flows (3) will provide calibration for the cooling algorithm and the rheologic
conditions for basalt used in the program. **Moon:** Distinct lava flows are visible in Mare Imbrium (4), found on slopes of 0.1° to 0.2° (5). The youngest Imbrium flows (4) have isolated leveed channels and large length/width ratios. Cooling and rheology algorithms likely will need to be changed to simulate such flows. **Mars:** Many distinct lava flows are present in the Tharsis area (6), typically on slopes of 1° to 5° (7). The program should be quite applicable to the best examples of these flows. **Venus:** Several of the lava flow fields identified on Venus (8) include individual flows traceable for hundreds of kilometers. Magellan altimetry indicates that flows in East Kawelu Planitia were emplaced on extremely shallow slopes of 0.02° to 0.07° (9). The program will be used to evaluate the need to accommodate cooling processes in the dense venusian atmosphere, and possibly eruption temperature and/or rheologic changes, to reproduce the observed aspect ratios of venusian flows on shallow slopes. Continued modeling should provide constraints on likely lava thickness, eruption temperature, and effusion rates for discreet lava flows observed on Venus.


Figure 1. Stereoscopic view of lava flow simulation on an inclined plane [Parameters used: flow rate = 30 m³ s⁻¹, effusion duration = 3 hr, calc interval = 1 s, grid cell size = 10 m, slope = 30°, gravity = 9.8 m s⁻², eruption temp = 1400 K, lava density = 2500 kg m⁻³]. View is for one hour after cessation of effusion, so that lava has drained from the central channel. Flow is 1 km long, with a maximum thickness at front of 6 m.