EXPERIMENTAL IMPACTS INTO VISCOUS FLUIDS: IMPLICATIONS FOR OSCILLATING PEAK MODELS OF CRATER FORMATION. *Jonathan H. Fink and Ronald Greeley, Department of Geology, Arizona State University, Tempe, Arizona 85287*

Rampart type impact craters on Mars and Ganymede are potential indicators of crustal volatile content. Gault and Greeley (1) produced craters with similar morphology during impact experiments into clay slurry targets. According to the model of Greeley et al. (2), successive collapses of an oscillating central peak send out surge waves of material that become preserved as concentric ejecta flow lobes. Fink et al. (3) expanded the above model to include targets with Bingham rheological properties having both viscosities and yield strengths. The main effect of viscosity is to limit the amount of energy and momentum transferred from the transient crater bowl to the first central peak.

In order to quantify the effects of viscosity on the formation of craters in Bingham targets, we conducted a series of 157 impacts into Newtonian viscous fluids whose viscosities ranged from 10^{-2} poises to 600 poises (1 poise = 0.1 Pa-s), while their surface tensions and densities remained nearly constant (4). Results for 70 experiments are shown in Figure 1, where we have plotted the ratio of central peak potential energy (Ep) to potential energy of the transient crater bowl (Ec), as a function of the ratio of Froude Number (Fr) to Reynold's Number (Re), $\eta/\rho g^{1/2} d^{3/2}$, where η and ρ = target viscosity and density, respectively, g = gravity, and d is the diameter of the transient crater bowl of maximum volume. The latter dimensionless group relates viscous forces to gravitational forces.

For low values of Fr/Re, the transfer of energy from crater bowl to central peak was nearly complete ($Ep/Ec \cong 1$). In this hydrodynamic regime, target viscosity had no apparent influence on central peak oscillations. At higher viscosities ($Fr/Re < 0.02$), the energy ratio remained nearly constant. For the range of values $0.02 < Fr/Re < 0.2$, the amount of energy transferred decreased markedly. For values above 0.2, central peaks no longer formed. Our experiments thus suggest that viscous resistance prevents formation of an oscillating central peak for values of Fr/Re greater than 0.2.

The above criterion allows estimation of relative volatile concentrations in different areas on a planetary surface, on the basis of the smallest sized rampart craters these areas contain. For instance, if a portion of Mars contained rampart craters whose minimum diameter was 10 km, and we assume values of g = 380 cm/s^2, ρ = 3.0 g/cm, and d = 5 km (based on the further assumption that the depth of the transient crater bowl is roughly equal to the radius of the final crater), then the viscosity of the ejecta slurry would have to be less than 10^{10} poises. All measured values of viscosity for terrestrial debris flows fall within this range. If the minimum crater size were 100 m, then viscosities would have to be less than 10^6 poises. This requirement implies a higher volatile content. Quantitative relations between water content and strength for debris flows have been experimentally determined (5), but comparable correlations for viscosity are lacking. Nonetheless, estimations of viscosities and volatile contents of different areas on a planet can be made on the basis of the minimum size of rampart craters they contain.

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Fink, J.H. and Greeley, R.

Figure 1. Plot of energy transfer from transient crater bowl to central peak for impact experiments into viscous fluids. Ep = potential energy of the first central peak; Ec = potential energy of the transient crater bowl; Fr = Froude Number, Re = Reynold's Number; Fr/Re = $\eta/\rho g^{1/2} d^{3/2}$. Insert depicts kinetic energy of projectile (E_k) being transferred first to transient crater bowl (Ec) and then to central peak (Ep).