ACOUSTIC FLUIDIZATION AND THE EXTRAORDINARY MOBILITY OF STURZSTROMS.

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Introduction: Sturzstroms are a rare category of rock avalanche that travel vast horizontal distances with only a comparatively small vertical drop in height. Their extraordinary mobility appears to be a consequence of sustained fluid-like behavior during motion, which persists even for driving stresses well below those normally associated with granular flows. One mechanism with the potential for explaining this temporary increase in the mobility of rock debris is acoustic fluidization; where transient, high-frequency pressure fluctuations, generated during the initial collapse and subsequent flow of a mass of rock debris, may locally relieve overburden stresses in the rock mass and thus reduce the frictional resistance to slip between fragments. In this paper we develop the acoustic fluidization model for the mechanics of sturzstroms, and discuss the conditions under which this process may facilitate self-sustaining fluid-like flow of large rock avalanches at low driving stresses.

Background: Sturzstroms are large (volume > 10^6 cubic metres) mass-movements of dry rock debris. They are unusually mobile: the ratio of their fall height *H* to run out length *L* is less than the typical value for small dry rock avalanches (~0.6). *H/L*, which is an approximate measure of the coefficient of friction of the rock avalanche, decreases with increasing avalanche volume [1,2]; in other words, the mobility of sturzstroms increases with avalanche volume. Large dry rock avalanches have been observed on many Solar System bodies. Furthermore, observations suggest sturzstroms "flow" like a fluid [3] (sturzstrom means "fall", or "collapse stream"). There is some geologic evidence for preservation of gross stratigraphy during motion [4]. It would appear that avalanches of a given volume on Mars have shorter relative runout (higher effective coefficient of friction) than Earth [5].

Acoustic Fluidization: The premise of the acoustic fluidization model for the high mobility of sturzstroms is that large, high-frequency pressure fluctuations, generated during the initial collapse and subsequent flow of a mass of rock debris, may locally relieve overburden stresses in the rock mass and thus sustain rapid fluid-like flow of the debris, even in the absence of large driving stresses [6, 7]. We have developed a mathematical rationale for describing the space- and time-dependent behavior of acoustic energy within a moving dry rock avalanche. Assuming that the propagation of high-frequency vibrations within a mass of rock debris is dominated by scattering, temporal and spatial changes in the acoustic energy field are a result of three processes: (1) Scattering of acoustic energy from regions of high energy to regions of low energy; (2) Dissipation of acoustic energy to thermal energy; and (3) Regeneration of acoustic energy as a result of shear within the avalanche.

For acoustic fluidization to be a viable model for explaining the mobility of sturzstroms, there must be an achievable balance between the first two processes and the last. That is, regeneration of acoustic energy during flow must be sufficient to balance the losses due to dissipation and scattering. Here we investigate the conditions for which acoustic fluidization may facilitate self-sustaining fluid-like motion of a dry rock avalanche using stea-y state analysis and hydrocode modeling.

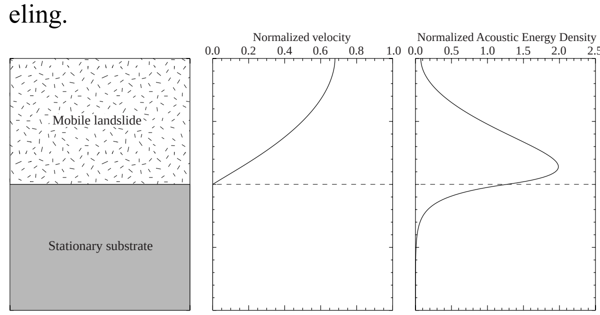

Figure 1: A typical steady-state solution to the acoustic fluidization equations for a dry rock avalanche. The left panel depicts the modeled situation of a mobile rock avalanche moving over a stationary substrate. The center panel illustrates the velocity profile through the flowing avalanche. The right panel shows that the acoustic energy is concentrated near the base of the avalanche.

Conclusions: Acoustic fluidization can increase the mobility of a dry rock avalanche. For realistic avalanche conditions, acoustic fluidization can facilitate self-sustaining motion of a dry rock avalanche (see Figure 1). Acoustic fluidization predicts that the avalanche will "flow" with an approximately constant effective viscosity. The steady-state solution for an acoustically fluidized rock avalanche may be obtained during hydrocode simulations of the initiation of a rock avalanche, provided that a small fraction of the kinetic energy of the rock fall is transferred to internal acoustic vibrational energy, or the avalanche has a modest initial velocity. Hence, acoustic fluidization can explain the extraordinary mobility of sturzstroms.

References and Acknowledgements: [1] Hsu, K. J. (1975) GSA Bulletin, 86, 129-140. [2] Shaller, P. J. (1991) Ph.D. Thesis, Caltech. [3] Heim, A. (1882) Deutschen Geologischen Gesellschaft, 34, 74-115. [4] Shreve (1968) GSA Special Paper, 108, 47. [5] McEwen (1989) Geology, 17, 1111-1114. [6] Melosh, H. J. (1979) JGR, 84, 7513-7520. [7] Melosh, H. J. (1987) Debris Flows/Avalanches: Process, Recognition and Mitigation, edited by J. E. Costa and G. F. Wieczorek, 41-49, GSA. This work was funded by NASA grant NAG5-11493