FRICTION MELTING MECHANICS: EXPERIMENTAL EVIDENCE RELEVANT TO IMPACT CRATERING

John Spray, Planetary and Space Science Centre, Department of Geology, University of New Brunswick, 2 Bailey Drive, Fredericton, New Brunswick E3B 5A3, Canada. Email: jgs@unb.ca

Introduction: Over the last decade or so, there has been a growing awareness that the impact process includes the localization of target deformation into fault systems of various widths and displacements. This is particularly the case during the modification stage of the formation of complex craters, where collapse and rebound features result in the displacement of enormous volumes of rock. In impact structures, the discretization of deformation is manifest in different arrays of slip systems from the microscopic (sub-mm) to megascopic (km-size) scales. If strain rates are sufficiently high, frictional melting of the fault walls will occur. The common development of friction melt-clast suspensions (pseudotachylytes) in fault zones (typically 1 cm thick for endogenic systems), including those associated with meteorite impact (typically up to 1 m thick), testify to the ability of such natural slip systems to frictionally melt fault walls (e.g., 1, 2).

Frictional melting hierarchy: Friction experiments using high-speed slip apparatus have enabled us to explore the mechanics of the melting process. These experiments reveal that the fracture toughnesses and shear yield strengths of the constituent minerals are critical to the melting path. These strengths are found to be dependent on mineral crystal structure and bond energy. A hierarchy of comminution and melting susceptibilities is apparent within the major rock-forming minerals, with, in order of decreasing melting susceptibility: phyllosilicates > inosilicates > tectosilicates > orthosilicates. The pre-melting condition is controlled by the elasticity of a given mineral species and its thermal conductivity. At a critical grain size, typically <1 micron, the volume of elastic-plastic deformation during grinding exceeds the fragment's ability to remove heat from the deforming outer zones and so the temperature rises to the melting point. Once this occurs, the melted species contributes to lowering the friction until a critical volume of melt is generated.

Friction Experiments: In this presentation, we report on a series of rotary friction experiments performed on Westerly granite at start velocities of 2.0-4.0 m s^{-1}, under a loads of 250-500 N until the system stalls (up to ~4 s). A typical sample configuration is shown right (Fig. 1). Interface temperature, velocity and force have been measured at intervals of 0.2 milliseconds. The results show that kinetic friction increases in direct proportion to temperature up to a critical value T_{cr}, whereupon the system changes from boundary lubrication (slip strengthening) to hydrodynamic lubrication (slip weakening) with an associated decrease in friction and temperature. For Westerly granite T_{cr} is ~1150 EC. This corresponds to the melting point of feldspar, which constitutes ~50% of the rock. If T_{cr} is exceeded in natural slip systems, which will depend on rock type, this can result in the generation of friction melt. T_{cr} tends to be easily exceeded in impact events, because collapse structures involve large (km-size), single-slip displacements (e.g., side wall slumping). This is in contrast to endogenic earthquake faults, where constrained

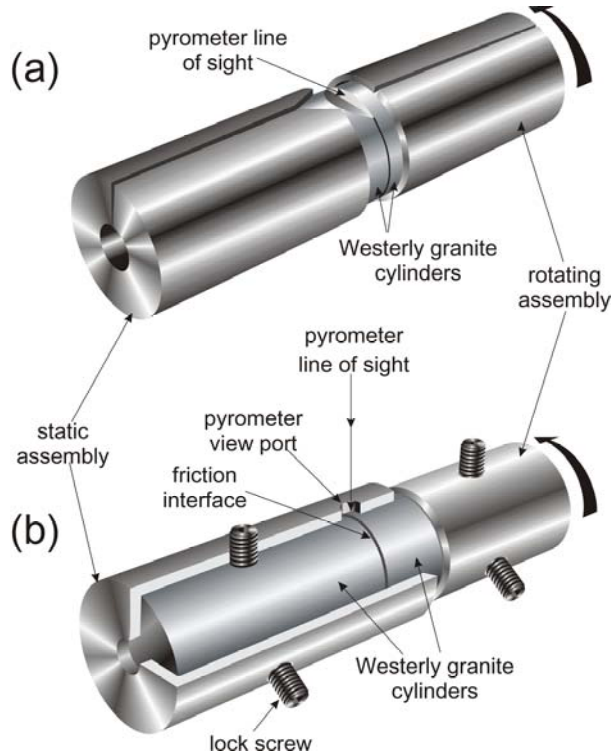

Figure 1. Sample holder design for (a) open runs and (b) closed runs (with cutaway for clarity). Rock cylinder diameter 37 mm

fault terminations act to limit the slip distance.

Mega-friction melts in impact structures: We explore the development of mega-pseudotachylyte systems (km-size) in impact structures in terms of collapse features. A prime example is the Frood-Stobie ore belt at Sudbury, which is currently the largest known example in the world. This is a pseudotachylyte breccia that is up to 1 km wide and 45 km length and hosts one of the largest known Cu-Ni sulfide orebodies. In this case, the acceleration of the fault mitigates decreasing friction due to lubrication because violent wall rock interactions introduce a continuous feed of clasts into the slip system. This is distinct from the smaller, pinned, endogenic slip systems, where lubrication feedback is prevalent.

References: [1] Sibson, R.H. (1975) *Geophys. J. R. Astron. Soc. 43*, 775-794. [2] Spray, J.G. (1997) *Geology 25*, 579-582.