MECHANISMS OF IN SITU ROCK DISPLACEMENT DURING HYPERVELOCITY IMPACT: FIELD AND MICROSCOPIC OBSERVATIONS

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Introduction: The nature of rock deformation due to hypervelocity impact is discussed, especially with regard to the larger terrestrial structures (e.g., Sudbury, Vredefort, Manicouagan). Based on field observations and thin section microscopy, evidence is presented for two end-members of rock response to extreme strain rates: (1) bulk deformation, due to pervasive fracture generation and ensuing micro-displacement with melting; (2) localized large-displacement faulting, accompanied by friction melt generation (pseudotachylytes). There is no evidence for bulk “fluidization” at the thin section scale, except where bulk melting has occurred during impact melt sheet generation, wherein truly fluid (igneous) rocks are formed.

S- and E-type fracture-fault systems: Bulk deformation in footwall rocks beneath the Sudbury Igneous Complex (melt sheet) is limited to a zone some 10-15 km beyond the contact with overlying melt. Fracture-microfault systems are typically a few mm thick and are akin to shock veins in meteorites. These have been referred to as S-type pseudotachylytes [1]. They may contain high-pressure polymorphs. Melting is probably due to a combination of shock and microslip. In this proximal footwall zone at Sudbury, there are 10-20 pervasive S-type veins per cubic meter, with the frequency decreasing progressively away from the melt sheet.

Localized, large-displacement faulting can be related to concentric and radial structures that appear to be formed during the modification stage of the cratering process. These post-date the shock wave and are primarily driven by gravitational forces and possible rebound effects. Movement on the concentric systems commonly occurs after movement on the radials. Movement on the concentric faults is typically significantly greater than that realized on the radial fracture-fault systems. Large displacement, single slip faults have been referred to as superfaults when displacement is >100 m in one event [2]. Under superfaulting conditions, thick (1-1000 m) friction melt (pseudotachylyte) bodies may result. These may be responsible for the rings seen in multiring impact basins on the moon and other planets. The thickest pseudotachylytes are formed when these faults undergo displacements of several kilometers in one slip event. Superfaults generate terraces in the larger impact structures. This class of pseudotachylyte has been referred to as E-type [1]. E-type pseudotachylytes are formed in the same way as endogenic fault-related pseudotachylytes, though displacements due to impact can be many orders of magnitude greater than those realized during regular faulting (the latter typically resulting in cm-wide pseudotachylyte veins).

Central uplifts: While S- and E-type pseudotachylytes have been documented with regard to melt sheet footwall occurrences, there are very few references made to them with regard to the internal structure of central uplifts. Central uplift mechanics remains poorly understood. How is it possible for vast volumes of rock to move, supposedly downwards (during compression) many kilometres, and then back up many kilometres (on decompression), and probably within seconds or minutes? In fact, there is little hard evidence that transient cavities are pushed downwards during compression and excavation (i.e., in a gross plastic/elastic manner). In so, cannot rebound be attributed merely to pressure release at a free surface? The internal structure of central uplifts has not been studied in any real systematic detail in the field. Work on smaller impact structures, such as Decaturville [3] reveals a crude concentric piston-like form, with the deepest level rocks being exposed in the centre of the uplift and successively higher level rocks being exposed around this core. The uplift is thus not chaotic, although each concentric zone appears to comprise blocks of coherent rock in a fragmental matrix (breccia) that has been well mixed. Preliminary work thus indicates that some uplifts are similar to telescopic hydraulic rams in their cylinder-within-cylinder structure. Whether the contacts between “cylinders” are sharp (i.e., fault bounded) or gradual (fluid like), is not yet clear.