GEOLOGICAL EVIDENCE FOR ACOUSTIC FLUIDIZATION IN LARGE IMPACT STRUCTURES. U. Riller[1] and D. Lieger[2], [1]School of Geography and Earth Sciences, McMaster University, Hamilton, Canada (rilleru@mcmaster.ca), [2]Museum of Natural History (Mineralogy), Humboldt University, Invalidenstrasse 43, 10115 Berlin, Germany.

Introduction: Acoustic fluidization of target rock has been invoked as mechanism accomplishing high deformation rates during transformation of transient craters into final craters with flat floors, notably of large impact structures [1, 2]. The modified concept of acoustic fluidization, known as the block oscillation model [2], predicts fragmentation of target rocks on the decameter to hundred meter scale. Apparently, such discontinuous deformation along with pressure fluctuations transiently lowers overall rock cohesion and allows target rock to behave mechanically as a fluid during cratering. However, geological evidence for fluid-like behavior of target rocks and its immediate regain in mechanical strength at the end of cratering does not seem to have been recognized in large terrestrial impact structures.

Although generally not attributed to acoustic fluidization, target rocks in the central portions of large terrestrial impact structures such as Sudbury, Canada, and Vredefort, South Africa, are characterized by the pervasive presence of fragment-rich pseudotachylite bodies. Debates regarding the formation of these bodies include the origin of melts, i.e., friction- versus shock-induced melting, their mobility, cause of target rock fragmentation and timing of breccia body formation with respect to cratering stages. Structural observations from Sudbury and Vredefort suggest that fragment-rich pseudotachylite zones may well be important agents of acoustic fluidization.

Results: The size of fragment-rich pseudotachylite bodies at both impact structures ranges from mm- to cm-wide veins, dm- to m-scale dikes, to up to hundreds of meters wide, irregular or pocket-like bodies. Despite pervasive fragmentation, target rocks of both impact structures are characterized by a remarkable structural continuity of pre-impact geological units and mineral fabrics on the decameter scale and larger. This continuity indicates that overall target rocks behaved mechanically as a continuum during crater formation and that slip on proposed, apparently kilometer-scale, impact-induced discontinuities is likely of minor importance during the crater modification, at least at the exposed crustal levels of both impact structures.

The geometry of pseudotachylite zone margins and fragments indicates that the zones are essentially fragment- and melt-filled fractures formed by dilation, i.e., volume increase of target rock. This is supported by strike separations of pre-impact markers at the zone boundaries, which are generally less than a few centimeters. Thus, the zones formed as tension gashes or hybrid shear faults. We failed to identify impact-induced shear faults that could potentially have generated friction melts and fragments. Where pseudotachylitic veins overstep each other, their respective tips are curved toward the neighboring vein, thereby isolating elliptical host rock fragments. This underscores the formation of pseudotachylite zones by discontinuous deformation on the outcrop scale.

Recognition of the pre-impact fit of marker points across pseudotachylitic veins and dikes allowed us to determine the components of maximum dilation vectors at a given outcrop surface at Vredefort. Measurement of the component vectors throughout the outer core of the Vredefort Dome indicates either radial or concentric stretching of material, regardless of breccia zone orientation. This is in agreement with strain accumulation predicted from numerical modeling [3] and suggests that pseudotachylite zones formed at an advanced stage of cratering, likely during formation and collapse of the central uplift.

Pre-impact configuration of fragments in large breccia zones and the paucity of fragments that are exotic with respect to the immediate host rock indicate that fragments were not transported distances larger than tens of meters. However, this may not apply for the pseudotachylitic matrix, i.e., former melt. Collectively, (1) overall dilation and volume increase during target rock fracturing, (2) incipient fragmentation and jigsaw geometry of fragments, (3) en-echelon vein geometry, (4) evidence for thermal corrosion of fragments and (5) apparent lack of bona fide shear faults point to an allochthonous origin of the melt.

Interpretation: Popular models of pseudotachylite formation assume that fragmentation and melt generation occur during a single process, either driven by gravitationally-induced shearing or slip on prominent discontinuities, or by the interaction of the shock wave with target rock. Our structural observations suggest that fracturing and melt generation are processes that are separated in space and time during cratering. Specifically, fracturing and fragmentation is related to dilation of target rock, which accomplished large-scale bending of the uplifted rocks during late stages of cratering [3]. Thereby, tensional fracture zones led to shape change of the crater floor, whereby differential displacement parallel to the zone walls is minimal, generally on the order of centimeters or less for pseudotachylite veins. This agrees with the observed structural continuity and overall mechanical coherence of target rocks during late-stage cratering. During this deformation, dilatational fracture zones formed likely low pressure zones into which melt, possibly drained from the overlying impact melt sheet, was drawn forcefully.

Based on our observations, fragment-rich pseudotachylite zones formed during crater modification, the cratering stage at which acoustic fluidization is believed to be active [2]. Thus, pseudotachylite zones may well constitute the discontinuities accomplishing acoustic fluidization. Other important characteristics of the block oscillation model of acoustic fluidization are the speed of sound, apparently much lower in the matrix between the blocks than in the blocks, and the immediate regain in mechanical strength of target rocks at the end of cratering [2]. Pseudotachylitic melt separating blocks and enveloping fragments during overall target rock fluidization and rapid solidification of the melt at the end of crater formation are in agreement respectively with these characteristics of the block oscillation model. We regard fragment-rich pseudotachylite bodies as viable candidates for accomplishing acoustic fluidization in large impact structures.

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