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Shock Studies of Kimberlite, Diamond and Brittle Embedded Particles

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The effects of uniaxial shock waves on diamond, glass, sapphire and a kimberlite, Tuffistic Kimberlite Breccia (TKB), have been investigated in plate impact experiments. The shock Hugoniot curve and the dynamic shear stress response of the kimberlite have been characterised at impact stresses up to 9 GPa and 5 GPa respectively. There is no clear Hugoniot Elastic Limit in TKB: plastic deformation is evident throughout the stress range investigated. The current data have been interpreted in the context of similar experiments in the literature and the principles of shock physics in order to accurately describe the shock response of an inhomogeneous geological material.

An experimental technique has been developed to photograph shock-induced failure in natural diamond slices (approximate dimensions 5 mm x 5 mm x 1 mm) embedded in a transparent polymer. Initial in-material compressive stresses ranged between 1 GPa and 3.5 GPa. For the high-speed photographic sequences, the interframe time was chosen to be 100 ns and the exposure time 50 ns. Shock-induced failure of diamond was characterised in nine experiments. The threshold compressive stress for failure of good quality natural diamond particles is between 2.0 and 2.8 GPa. Failure was found to be most dependent on shock wave amplitude, pre-existing flaws and birefringent internal stresses. Cracks have been observed moving faster than the Rayleigh wave velocity in diamond due to initiation of secondary flaws on microscopic scales ahead of propagating crack tips. The experimental technique was developed using embedded glass and sapphire specimens, which have been compared with diamond, revealing progressively more catastrophic failure for greater shock wave amplitudes in weaker materials. Time-dependent digital image analysis and fragmented particle recovery techniques have also been developed. The mass distribution of recovered diamond fragments has been characterised. Application of this research to the development of a computational model for diamond mining is discussed.