Simulations of Shock Wave Propagation in Heterogeneous Solids

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Studies of shock propagation in heterogeneous materials are important for the interpretation of impact deformation and impact metamorphosis of rocks, in particular the formation of high-pressure phases and of impact melt. The different behaviour of the components of a polymineralic rock under compression makes its response to shock loading more complicated than that of a single material. Reflection, refraction, and interference of shock waves caused by inhomogeneities lead to localised concentrations of pressure, temperature, and deformation rate, and to phase transitions. Such effects need to be considered if pressure and temperature during impact loading are gauged by the shock damage of a material.

We have simulated numerically the shock compression of complex media in selected geometries with the aim of modelling shock recovery experiments and have calculated changes of pressure, density and temperature due to the impact loading. Our work is motivated by laboratory studies of probes composed of materials with a strong contrast in their compressive behaviour like dunite and quartzite [1] where partial melting had been observed as result of the heterogeneity of the probes.

In the simulations, the two-dimensional version of the hydrocode SALE [2] has been employed. Because phase transitions must be expected in the material at the temperatures and pressures achieved during compression, the equations of state must be able to describe them in a thermodynamically consistent way. The ANEOS package [3] has been used for this purpose. For rectangular inclusions, the simulations have been performed in Lagrangian mode. If phase boundaries intersect simulation cells which is the case for inclined material interfaces, the simulations have been performed in Eulerian mode which has been extended to two different materials in one cell. We have observed reversible phase transitions in the target, in particular the formation of high-pressure phases, which affect considerably the propagation of the shock wave. Shock heating alone is not sufficient for melt formation in the systems considered in the present study, but localised shear at material boundaries results in a significant temperature rise and makes partial melting possible.

[1] Kenkmann, Th. et al. (2000), Meteoritics & Planet. Sci. 35, 1275
[2] Amsden, A. A. et al. (1980), Los Alamos Scientific Laboratory Report LA-8095
[3] Thompson, S. L., Lauson, H. S. (1972), Sandia National Laboratory Report SC-RR-71 0714