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Large impact cratering: Experimental approach

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Abstract

Downscaling the material properties of a test target so that the same type of damages observed in nature is reproduced in experiments at a much lower impact velocity is proposed and tested by comparing experiment against natural counterparts at large (readjusted) meteorite impact craters on Earth.

1. Introduction

Research on large meteorite impact craters on planetary surfaces has been mostly focusing on the crater region where a fluid like behavior of the target appears appropriate. This zone is small compared to the damaged zone below and around the crater, where the response is governed by the strength of the material (Fig. 1). The damages, fracturing and plastic deformations at all scales are difficult to recognize and interpret at natural terrestrial sites, owing to convergence with features which are usually also present at the initial stage in the target.

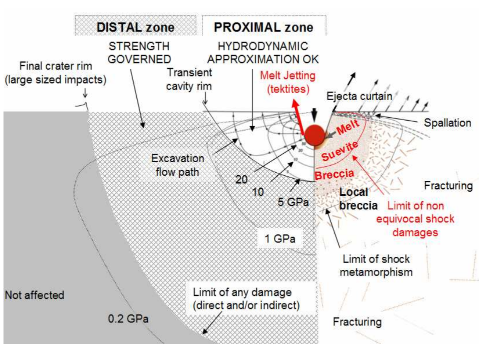

Figure 1: Schematic interpretative cross-section of large impact crater on Earth (modified after [1]).

Reproducing these features by experiments is not practical either because of physical limitations in accelerating sizeable projectiles at velocities required to produce a crater on rock materials. To overcome the limitations it is proposed to downscale the material properties of the test target.

2. Results

The proposal is tested using data of [2-4] on concrete-like granular organic material recovered after experiments. Damages and mechanisms at work in the later are compared to natural effects observed at distal zone of large terrestrial impact structures where projectile impact velocity is #3 orders of magnitude higher than in the impact experiment. Despite huge differences of scales and properties, the later reproduces many of the most significant damages and mechanisms in the natural counterparts. Those include mega-faulting and mega-block zoning (Fig. 2), localized fracturing up to breccia dike formation (Fig. 2-4) and local severe damages up to phase transition and local melting at the scale of individual crystals and below (Fig. 2C and 4).

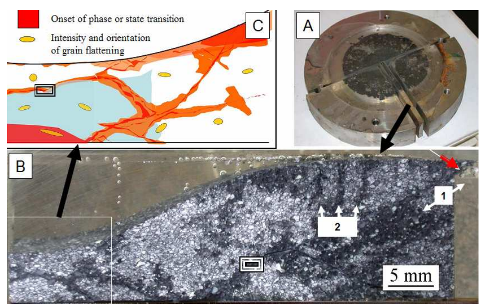

Figure 2: A- Recovered steel encased target. B-Half axial cross-section: 1-low angle brecciated fault, 2-vertical circumferential faults. C- Map of damage intensity in the central zone (modified after [4]).

3. Discussion

The explanation of the similarities reported above comes from the mechanical properties of the test material and from the mechanical conditions of the test. The role of confinement appears a significant parameter, probably overlooked in mechanical interpretations at large impact craters. The test material demonstrates i) a quasi-brittle behaviour, with a brittle to ductile transition taking place at low stress levels, ii) a crystal brittleness that allows for fragmentation at low stress triaxiality levels, iii) a crystal plasticity that allows for some local strain accommodation under confining pressure, iv) a localization behaviour displaying a wide range of responses, brittle to ductile, with accompanying clear thermal effects, v) a solid-solid phase transformation and a solid-liquid/solid-gas transformation occurring at “low” temperature (compared to minerals). All these characteristics are similar to those of silicate rocks and minerals, excepted the levels of stress and temperature involved **which are considerably reduced** in the organic material compared to rocks.

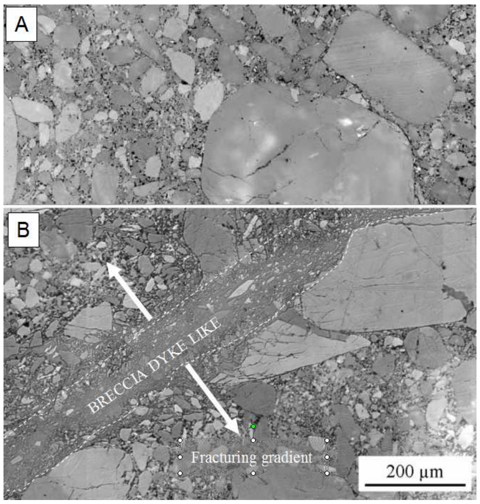

Figure 3: Polished cross-sections seen under reflected polarized light microscopy. A- Pristine material, B- Recovered after impact: detail of the framed zone in the center of Fig. 2B (modified after [3]).

4. Conclusions

A downscaled experimental approach where both impact velocity and material properties are significantly “reduced” compared to natural conditions, can reproduce the effects observed at large natural impact and the behavior of rocks at the boarder and below the transient cavity. Others type granular organic materials with similar behavior yet less “reactive” than the one in [2-4], should probably be tested in view of an academic development of the proposed experimental approach. The later could be of considerable interest for both the defense and the meteorite impact communities, also opening the route for further physical modeling applications.

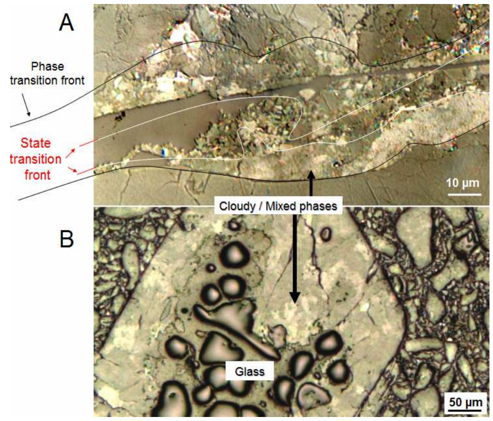

Figure 4: Polished cross-sections seen under reflected polarized light microscopy. A- Recovered after impact: detail of the framed zone Fig. 2C (modified after [2, 3]). Friction induced phase transition and melting forming narrow bands along shear fractures cross cutting the target (see Fig. 2), B- Recovered after frozen combustion experiment (from [4]).

Acknowledgements

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