DYNAMIC TENSILE STRENGTH OF CRUSTAL ROCKS AND APPLICATION TO IMPACT CRATERING.

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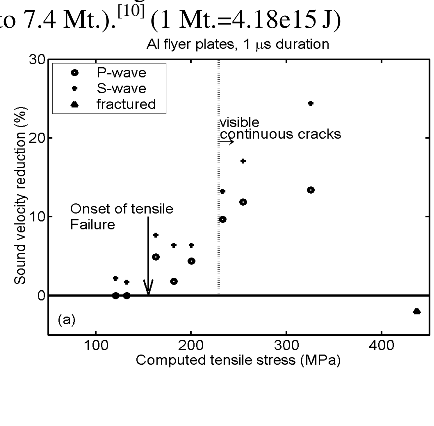
Dynamic tensile strengths of two crustal rocks, San Marcos gabbro and Coconino sandstone (Meteor Crater, Arizona), were determined by carrying out flat plate impact experiments. Porosity of San Marcos gabbro is very low,[1] and the reported porosity for Coconino sandstone is ~25%.[2] Aluminum flyer plates were used for gabbro with impact velocities of 13 to 50 m/s, which produce tensile stresses in the range of 120 to 450 MPa. PMMA flyer plates were used for sandstone with impact velocities of 5 to 25 m/s, resulting tensile stresses in the range of ~13 to 55 MPa. Impact was normal to the bedding of sandstone. Tensile duration times for two cases were ~1 and ~2.3 μs, respectively. Pre-shot and post-shot ultrasonic P and S wave velocities were measured for the targets.

Velocity reduction for gabbro occurred at ~150 MPa (Fig. 1a), very close to the earlier result determined by microscopic examination.[1] The reduction of S wave is slightly higher than that of P wave. This indicates that the impact-induced cracks were either aligned,[3] or there were residual fluids within cracks,[4] or both. Data for sandstone velocity reduction was few and scattered caused by its high porosity (Fig. 1b). The range of dynamic tensile strength of Coconino sandstone is within 25 and 30 MPa (Fig. 1b). Obvious radial cracks at certain stresses indicate that deformation was not restricted to one dimensional strain as being assumed. Spall fragmentation occurred above 40 MPa (Fig. 1b).

The combination of impact velocities, U (km/s), and impactor radii, a_0 (m), are constrained by Meteor Crater fracture depth, ~850 m,[5] and the dynamic tensile fracture strength from our experiments, 40 MPa (Fig. 2). Volume of the crater for each impact was calculated using $V = 0.009mU^{1.65}$,[6] where V is crater volume (m^3), m is the mass of the impactor (kg). Volume of impact with U = 28 km/s, a_0 = 10 m is close to the real Meteor Crater volume, 7.6e7 m^3.[7] Impact energy for this case is 3.08 Mt., which agrees well with theoretical calculation (3.3 to 7.4 Mt.).[10] (1 Mt.=4.18e15 J)



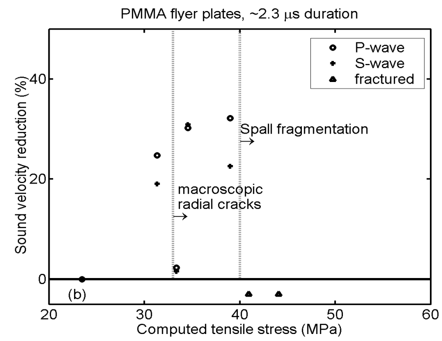


Figure 1: Velocity measurements for *(a)* gabbro and *(b)* sandstone experiments. Dashed line in (a) indicates pressure above which visible continuous cracks occurred. Dashed lines in (b) indicate pressures above which macroscopic radial cracks and spall fragmentation occurred.

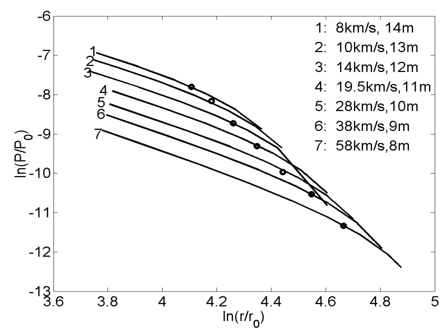


Figure 2: Normalized tensile pressure P at different depths, r, for sets of impact velocity U (km/s), and impactor radius r_0 (m) constrained by fracture depth of Meteor Crater and dynamic tensile fracture strength of Coconino Sandstone. P_0 is initial impact pressure, $P=P_r-P_z$, where $P_r=P_0(r/r_0)^{-n}$,[8] n is function of U[9] and P_z is the lithostatic pressure. Circles represent r = 850 m and P = 40 MPa.

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