# Analogue study of bomb sag formation: effects of substrate properties and impact velocity

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We performed analogue experiments to determine the relationship between the wetness of the substrate and the velocity and density of impacting clasts and 1) the formation (or not) of bomb sags, 2) the morphology of the impact crater, and 3) the penetration depth of the clast. Downward deflection of layering only occurs for water-saturated substrates. Collision angles < 20 degrees from vertical are needed to produce bomb sags in which the bomb is retained in its crater. Penetration depth is proportional to impact velocity squared and hence the impact energy.

To illustrate the potential usefulness of the experiments, we apply scaling laws obtained from the experiments to interpret the observation by the Mars Exploration Rover Spirit of a bomb sag at Home Plate, Mars. The downward deflection of beds seen on Mars is consistent with water-saturated sediment in the laboratory experiments. From the experiments we infer an impact velocity up to 40 m/s, lower than ejection velocities during phreatic and phreatomagmatic eruptions on Earth. If this velocity represents the terminal subaerial impact velocity, atmospheric density exceeded 0.4 kg/m3 at the time of eruption, much higher than at present.