The Meteoritical Society

Meteoritics & Planetary Science 43, Nr 12, 1915–1916 (2008)
http://meteoritics.org

Proceedings of the Workshop, Bridging the Gap II: Effect of Target Properties on the Impact Cratering Process

The geologic process of planetary impact cratering involves the interaction of extremely high-velocity, multiphase processes that occur over size and time scales that span several orders of magnitude. Understanding this process requires conducting research bridging a variety of disparate scientific disciplines. In the past, there has been a perceived gap in communication between those employing physics-based approaches to impact studies (e.g., numerical modeling, laboratory experiments) and those using a more geology-based approach (e.g., field studies, remote sensing). To improve interaction between "modelers" and "observationalists," the initial Bridging the Gap workshop was convened in Houston in 2003 (proceedings published in the February 2004 issue of *Meteoritics & Planetary Science*). A key aspect of the workshop was that modelers were required to address what observations would better constrain their physical models, and observationalists were required to discuss how their observations could constrain modeling efforts. That initial workshop spurred improved interdisciplinary cooperation in impact cratering studies. For example, we share the view that studies that incorporate both modeling and observations are much more common than in the past, a situation reflected in the interdisciplinary nature of many of the papers presented in this proceedings issue. Participants in that initial workshop also recommended specific research projects, and results from a couple of those efforts are presented here.

In September 2007, approximately 60 scientists gathered at the Headquarters of the Canadian Space Agency near Montreal, Quebec, for the second workshop in the Bridging the Gap series, titled "Bridging the Gap II: Effect of Target Properties on the Impact Cratering Process" (http://www.lpi.usra.edu/meetings/gap2007). This recent workshop addressed the broad topic of how differing target properties affect the cratering process. This workshop featured a 2-day fieldtrip to the ~54 km diameter Charlevoix impact structure, near Quebec City. This fieldtrip, led by John Spray and Mike Dence, exemplifies the spirit of the Bridging the Gap workshops in allowing scientists from various backgrounds to discuss and debate the rocks from their various viewpoints. In this special proceedings issue of *Meteoritics & Planetary Science* we present eleven papers that span a variety of workshop-related topics.

The first Bridging the Gap conference specified the need for validation of numerical modeling codes by comparison with experimental impacts and explosion craters. Over the last three years, colleagues at multiple institutions have been involved in efforts to systematically compare several commonly used codes by conducting benchmark simulations of idealized problems and validation tests against well-characterized experiments. In this issue's first paper, Pierazzo and colleagues present the results of the first phase of this effort in a paper titled "Validation of numerical codes for impact and explosion cratering: Impacts on strengthless and metal targets." They compare benchmark calculations of shock wave propagation in aluminum-on-aluminum impacts and validation simulations of vertical impacts into water and aluminum alloys. Overall, these initial results show modest inter-code variability and good agreement with experiments.

One of the specific suggestions that came from the group discussions at the first Bridging the Gap meeting was the need for comparative field and analytical studies of terrestrial craters in the 15–30 km diameter range. Craters of this size display all the attributes of complex impact craters yet are small enough that systematic studies are possible within a few years; there are also several of these structures in a variety of targets and preservational states, enabling comparisons to be made. Two papers in this issue use comparative studies of terrestrial craters in this size range to address the effects of target properties on specific aspects of complex crater formation. Osinski and colleagues conduct a comparative study of the Haughton, Mistastin, and Ries impact structures in "The effect of target lithology on the products of impact melting." Previous studies had suggested that sedimentary targets produced less impact melt than crystalline targets. Osinski and colleagues suggest that similar amounts of melt are produced but that the nature of the melt products differ in their textural, chemical and physical properties. Collins and colleagues compare and contrast the Ries, Haughton, and El'gygytgyn structures in "Mid-sized complex crater formation in mixed crystalline-sedimentary targets: Insight from modeling and observation." These three craters formed in crystalline targets overlain by sedimentary layers of varying thickness. In a study that combines observations and modeling, they were able to identify systematic ways in which the thickness of the sedimentary layer affects the formation process.

The next four papers study different aspects of water, in both solid and liquid form, as a target material in the cratering process. In "The effect of target properties on crater morphology: Comparison of central peak craters on the Moon and Ganymede," Bray and colleagues focus on the effects of ice versus rock as a target in complex crater formation. They examine differences in morphology of central peak craters between the Moon and Ganymede and they use their observations to constrain numerical models of central peak formation. Their results seem to favor mechanisms for central peak formation that rely on floor uplift rather than rim collapse. In "Impact crater formation in icy layered terrains on Mars," Senft and Stewart examine the effects of crater formation on Mars in the presence of a near-surface icy layer. Through a series of numerical models, they systematically explored the effects of varied ice fraction, thickness, and depth to the icy layer. They identify trends and compare their models to observations of Martian complex craters. Their results indicate that the cratering record is consistent with the widespread presence of near-surface icy layers on Mars. Milner, Baldwin, and Burchell, in "Laboratory investigations of marine impact events: Factors influencing crater formation and projectile survivability," have conducted a series of experiments to examine the role that a liquid water layer plays in planetary crater formation. These experiments are particularly relevant to the Earth where most impacts occur into the ocean. The authors conducted a variety of experiments that explored the parameter spaces of projectile diameter to water layer thickness, impact velocity, impact angle, and projectile density. They focused on the effects on crater morphology and impactor survivability. To partially explain their observations, they observed and numerically modeled projectile velocity decay as it traverses a water layer. Cox and colleagues, in "Impact penetration of Europa's ice crust as a mechanism for formation of chaos terrain," address the unique target conditions of an ice layer overlaying a water layer. They speculate that the "chaos terrain" on Europa may result from impacts that penetrate through that planet's icy shell into a subsurface ocean.

The final four papers focus on using field studies to make inferences about the mechanics of the cratering process. In "Constraints on central uplift structure from the Manicouagan impact crater," Spray and Thompson examine recent results from drilling at the Manicouagan impact structure. Manicouagan forms a 55 km in diameter island in northern Quebec with excellent shoreline exposures of its well-preserved melt sheet. The new drilling results show that in places the melt sheet is up to 1500 m thick, much thicker than previously thought. The inferred geometry of the basement rocks beneath the melt sheet has led the authors to conclude, among other things, that uplift of the central structure occurred along high-angle, large-displacement faults. This interpretation has significant implications for the mechanics of large complex crater formation. Poelchau and Kenkmann, in "Asymmetric signatures in simple craters as an indicator for an oblique impact direction," present methodologies for assessing impact direction from the remnants of an oblique impact. These remnants are expressed as a bilateral symmetry in such features as the proximal ejecta, overturned flap, and crater rim. The methods involve measuring the deviation of features such as ejecta lineations and bedding plane strikes from axisymmetry. They present case studies from Tooting crater on Mars and Wolfe Creek crater in Australia. For the latter, their use of bedding plane orientation may be applicable for inferring impact direction from eroded impact structures. In "Textural constraints on the formation of impact spherules: A case study from the Dales Gorge BIF, Paleoproterozoic Hamersley Group of Western Australia," Sweeney and Simonson present a case study of 2.5 billion year-old impact ejecta preserved in the stratigraphic record in Western Australia. Their study has important implications for the formation and emplacement of impact spherules, as they identify important departures from the prototypical Cretaceous-Paleogene impact event. Osinski and colleagues, in "The Dakhleh Glass: Product of an impact airburst or cratering event in the Western Desert of Egypt?" examine an unusual glass that occurs over a large area in the Dakhleh Oasis, Egypt. Their combination of previous modeling results with a number of lines of observational evidence suggest that the Dakhleh Glass results from a near-surface airburst that generated glass and related products in the sedimentary target but no impact crater. Airburst events should be common on Earth, and this work may serve as a model for future recognition in the geologic record of such events.

We wish to thank the authors, reviewers, and *MAPS* staff for their efforts that made this special issue possible. We also would like to acknowledge the support of the workshop sponsors, the efforts of the scientific organizing committee, and the enthusiastic workshop participants for making this second Bridging the Gap workshop another success. We enjoyed convening the workshop and editing this special issue, and we hope that this workshop reinvigorated the cooperation and coordination efforts among impact investigators from different fields.

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