

# The Role of Outburst Floods in Earth and Planetary Evolution

5–9 June 2023 | Camp Delany, Coulee City, Washington, USA

## CONVENERS

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## ATTENDEES

Pablo Iribarren Anacona, Victor Baker, Juan Ballesteros, Emily Bamber, Eric Barefoot, Gerardo Benito, Nathaniel Bergman, Sebastien Bertrand, Bruce Bjornstad, Annie Borch, Abby Burlingame, Jonathan Burton, Sami Cargill, Paul Carling, Kalpana Chaudhari, John Clague, Neil Coleman, Alan Condron, Kristin Cook, Brenda Covington, Jonas Donnenfield, Adam Emmer, Steve Evans, Caleb Fassett, Małgorzata Frydrych, Daniel Garcia-Castellanos, David George, Alan Gillespie, Timothy Goudge, Gordon Grant, Ralph Haugerud, Juergen Herget, Amanda Hoke, Kyle House, Kate Huntington, Tómas Jóhannesson, Jeff Kargel, Kyoko Kataoka, Oliver Korup, Isaac Larsen, Justin Lawrence, Karin Lehnigk, Jerome Lesemann, Joe Levy, Tao Liu, Lucy Luevano, Natalie Lützwow, Dorothy Merritts, Aaron Micallef, Brendan Miller, Susannah Morey, Srinanda Nath, Jim O’Connor, Summer Praetorius, David Puhl, Justin Radford, Martin Roy, Kelly Russell, Rannveig Skoglund, Vijayan Sivaprahasam, Larry Smith,

Alex Sodeman, Mike Tilston, Georg Veh, Richard Waitt, Mo Walczak, Huiying Wang, Ping Wang, Sasha Warren, Greta Wells, Matt Westoby, Ian Yuh, Anita Zambrowska

## FIELD TRIP LEADERS

Victor Baker, University of Arizona; Isaac Larsen, University of Massachusetts–Amherst; Karin Lehnigk, Georgia Institute of Technology; Jerome Lesemann, Vancouver Island University; Jim O’Connor, U.S. Geological Survey; Richard Waitt, U.S. Geological Survey

## OVERVIEW

Outburst floods—those floods caused by the breaching of natural or constructed dams—play a significant role in shaping landscapes, impacting societies, and influencing Earth’s systems. The year 2023 marks the centennial anniversary of J Harlen Bretz’s first publication on the “Spokane floods” in the “Channeled Scabland,” which appeared in the Sept. 1923 issue of *GSA Bulletin* (v. 34, p. 573–608). This paper and several more in the next few years kickstarted research on outburst flood science and set off a decades-long debate about the role of catastrophic floods in landscape evolution. Since then, the field has expanded from its origins in eastern Washington to sites across the globe and on other planets, covering myriad aspects of outburst flood processes and effects.

The Penrose Conference aimed to mark the centennial by examining the past century of outburst flood science and looking ahead to the next 100 years of research.

Camp Delany—situated in the Dry Falls cataract plunge pool in the Channeled Scabland—served as an inspiring backdrop for these discussions and an ideal point of departure for field trips. Conference sessions were organized around four themes: (1) the Channeled Scabland and Bretz’s “Spokane floods,” now known as the Missoula floods from their source in Pleistocene glacial Lake Missoula; (2) outburst floods as a universal process, grouped by geographic region: North and South America; Eurasia; and Mars and other planets; (3) mechanics of outburst flood processes; and (4) broader implications of outburst floods, including modern hazards, landscape evolution, and Earth system impacts. The week produced inspiring discussions on the history



Camp Delany, Dry Falls

Figure 1. Dry Falls cataract complex and Camp Delany, Washington. Photograph by Bruce Bjornstad.



Figure 2. Group photo of conference attendees. Drone image by Bruce Bjornstad.

of outburst flood science, presented state-of-the-art developments in the field, and identified research gaps and future directions. Of equal importance, it fostered collaborations among the international outburst flood community and facilitated knowledge exchange with residents of this incredible landscape, including members of the Confederated Tribes of the Colville Reservation, the National Park Service, and Washington State Parks.

## CONFERENCE DETAILS

The conference took place at Camp Delany, a rustic retreat center within Sun Lakes–Dry Falls Washington State Park near Coulee City, Washington. Camp Delany lies within the plunge pool of the Grand Coulee cataract complex, which was carved by the Missoula floods and provided a stunning setting for discussing outburst flood science (Fig. 1). Numerous attendees commented on the drama of presenting talks and eating meals in the shadow of canyon walls sculpted by outburst floods. The camp offered tent and cabin accommodations, a large meeting room, kitchen facilities, and indoor and outdoor dining areas (and an abundant mosquito population).

The conference included 70 participants (Fig. 2) from institutions in 16 countries on four continents (Fig. 3), as well as three members of the Confederated Tribes of the Colville Reservation. Of the participants, 31% identified as female, 17% as graduate students, and 21% as early career researchers (<10 years post-PhD completion). The conference emphasized student and early career researcher participation by giving extended oral presentation time to students and early career attendees, reserving time for “students first” questions following talks, and organizing a mentoring program by pairing students and early career scientists with more senior scientists to encourage one-on-one conversations on research and professional development.

Discussion took place through a variety of presentation formats:

- Oral presentations (42 talks)
- Poster sessions (24 posters), introduced by lightning talks
- One plenary talk on the history of outburst flood science
- One panel discussion on “Traditional Ecologic Knowledge and Understanding of Outburst Floods” involving seven conference participants: representatives from the Confederated Tribes of the Colville Reservation, National Park Service rangers, and

scientists from five countries who discussed Indigenous perspectives on flood landscapes across the world

- Two field trips: a full-day trip to inspect iconic outburst flood landforms in the northwest Channeled Scabland and a half-day trip focused on flood erosion and deposition in Grand Coulee
- Breakout sessions organized by emergent, overarching themes of the week with the goal of charting “the next 100 years of outburst flood science”
- Recreational activities including trivia night, hikes and swims in the surrounding Sun Lakes–Dry Falls State Park, international volleyball, musical jam sessions around the campfire, and a guided tour of the Dry Falls Visitor Center by a Washington State Parks interpretative ranger
- The OutBees: a final-night talent show featuring music, poems, skits, and a competition to correctly pronounce “jökulhlaup” (appropriately judged by an Icelandic participant), as well as presentation awards for categories such as “Best Picture,” “Best Mystery Flood,” and “Best Original Screenplay”

Generous sponsorship from the Geological Society of America and the National Science Foundation enabled the conveners to cover full registration fees and partial travel support for all students and early career participants.

## EMERGENT THEMES

Several key themes emerged during the week. First, despite the great diversity of outburst flood science—spanning geographic regions, planets, methods, and time periods—many researchers grapple with the same underlying questions. What is the role of outburst floods in landscape evolution, and how do landscapes recover post-flood? How scalable is a single flood event to different landscapes, time periods, or triggering mechanisms? How can we most effectively integrate numerical models and field studies? What new methods or approaches are needed to address remaining knowledge gaps?

The two field trips illustrated many of these themes. Though focused on the Missoula floods in the Channeled Scabland, field trip stops provoked discussions on other flood landscapes across the solar system, as well as paleoflood reconstruction challenges, flood erosional mechanics, sediment transport, and tracing flood-water sources. The trips also offered opportunities for informal





**Figure 3. Map of conference attendee institutions (regionally grouped).** Basemap credit: United Nations Geospatial Contributor: UNGIS, UNGSC, Field Missions.

conversations among participants—networking is often more impactful when done while digging through paleolake sediment sequences or examining flood-deposited boulders.

Another key theme was the importance of tackling research questions with an interdisciplinary, multi-method approach. Presentations described linking onshore and offshore records to reconstruct flood impacts on ocean circulation and climate; combining different geochronological techniques to date paleofloods; and linking remote sensing, field observations, and modeling results. They also demonstrated the lessons that can be learned from other study sites—for example, recognizing similar depositional sequences from floods on different continents; comparing erosional features on Earth and Mars; or adapting early warning systems to different flood basins.

Finally, hearing perspectives from Colville Reservation tribal members both in the meeting room and at field trip stops provided powerful insight on the role these landscapes play outside the sphere of the geosciences alone—as ancestral lands, cultural sites, and (as illustrated by the National Park Service and Washington State Park participants) recreational and educational places. Situating outburst flood science within these contexts was a unique and powerful aspect of this conference that many attendees appreciated. It also demonstrated the value and responsibility of exchanging knowledge between different groups.

## OUTBURST FLOOD MEETING OUTCOMES

A classic outcome of such meetings is discussion and consideration of future research challenges and directions. This was the case here, when, on the final afternoon, participants met in breakout groups to discuss emergent themes with the aim of charting a course for the next 100 years of outburst flood research. We identified the following action points:

- Increase interdisciplinary communication and collaboration among geoscientists, engineers, oceanographers, etc., via working groups, conferences, and special journal issues.

- Study outburst floods with a systems approach—for example, considering the sediment impact from source to sink, not just deposits within a single valley.
- Link different flood records—for example, terrestrial and marine records, different geochronological data sets, etc.
- Balance and incorporate multiple methods—field observations, remote sensing, numerical models, and physical experimentation studies.
- Develop a database of flood events on Earth and other planets.
- “Share your science”—the importance of communicating research to society for both outreach and policy reasons (e.g., flood disaster mitigation strategies).
- Create a listserv for the outburst flood community, as well as a subgroup for students and early career scientists.

Another outcome, possibly more gratifying to the convenors (who may not fully witness the next 100 years of outburst flood research), has been the continued engagement among outburst flood researchers, especially early career scientists. Some of this was manifest formally in an American Geophysical Union session in December 2023, but much of it has been accomplished informally through proposal sharing, social media groups, and new and renewed collaborations.

Overall, this Penrose Conference affirmed that the future is bright for the next century of outburst flood science. The field continues to expand in new geographic, thematic, and methodological directions, and it involves an increasingly diverse group of scientists from across the globe who strive for effective collaboration and communication. Despite a century of study, the Channeled Scabland—like other outburst flood landscapes—still holds fascinating unanswered questions for all who explore it. We are excited to see what questions and answers the coming decades will bring.

## ACKNOWLEDGMENTS

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