Developing a New Paradigm for the Late Cretaceous to Eocene North American Cordillera: A Dominantly Oblique Plate Boundary

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An increasing number of robust data sets provide support for models of obliquely convergent plate motion along the western North America margin since the mid-Cretaceous. Furthermore, a variety of data sets indicate significant terrane translation along this oblique margin from the Jurassic until the Eocene, with dextral motion starting in the mid-Cretaceous or earlier. The original hypothesis of far-traveled terranes was based on paleomagnetic data from the northern Cordillera (e.g., Beck and Noson, 1972; Wynne et al., 1995; Irving et al., 1996; Enkin, 2006). A new group of reconstructions for the Pacific realm and North America have been developed based on tectonic analysis of subducted plates interpreted using seismic tomography (Sigloch and Mihalynuk, 2013, 2017; Clennett et al., 2020; Fuston and Wu, 2021). In addition, detrital zircon analysis has provided another data set that can potentially test between different models (e.g., Garver and Davidson, 2015; Matthews et al., 2017; Sauer et al., 2019; Boivin et al., 2022).

The objective of this Penrose Conference was to bring together an international group of scientists, from a variety of different subdisciplines and professional career stages, to address the problem of obliquely converging plate boundaries, terrane collisions, and strike-slip tectonism along the western North America Cordillera. The conference participants met for six full days of talks and field trips in western Idaho. The first and fifth days included field trips to visit the accretionary margin—modified by a major transpressional shear zone—in western Idaho, showing the abundant evidence in this region for significant dextral strike-slip motion. On the second day, participants presented all three major models for the Cretaceous–Paleogene tectonic evolution of the North American Cordillera. For each model, both a geologist and a geophysicist presented data based on exposed crustal rocks and/or mantle tomography. Each of the remaining three days was devoted to a section of the North American Cordillera (Northern, Southern, Central) and contained two keynote talks, a poster session with lightning talk introductions, breakout groups, breakout group reporting, a panel discussion, and whole-group discussions. Below we address the conference goals and how we achieved them during the conference.

CONFERENCE GOALS

Bring together people across borders and disciplines. A broad range of participants was important for discussing the 4D obliquely convergent history of the North American Cordillera. Participants came from the U.S., Mexico, and Canada, ensuring that the presented data and discussions were not limited by national borders. Participants used a variety of different data sets—including field-based structural geology and sedimentology, paleomagnetism, geochronology, geochemistry, mantle tomography, etc.—to support major tectonic models for the North American Cordillera. The goal was to ensure that people were able to

Strongly foliated orthogneiss, deformed by the western Idaho shear zone, exposed in the canyon country of Idaho, USA. The view is to the south and the foliation dips steeply east, rotated from its pre-Miocene vertical orientation by normal faulting. Photo by Basil Tikoff.

talk to fellow scientists within their geoscience subdiscipline, but also, more importantly, to discuss with other subdisciplines how different data sets can be integrated. Finally, participants in attendance supported different models of the North American Cordillera, including, but not limited to, westward subduction, flat-slab subduction, and major collision and translation. It was critical to bring together scientists to reconcile how the different data sets can be integrated in space and time to work toward a model consensus and discuss critical new data sets that need to be collected to better understand the tectonic system.

Find consensus where it exists. Some topics at the conference were, of course, contentious (e.g., large-scale terrane translation). The meeting started with a discussion about GSA's RISE initiative, which advocates for respecting your colleagues and making comments and asking questions in a non-aggressive, inclusive manner. It was emphasized that we all have the same goal of better understanding the North American Cordillera and that the Penrose Conference was a rare opportunity to discuss this orogenic system with a variety of scientists with different backgrounds, including different biases. To further set the tone for the conference, the first day of talks included a presentation about the role of uncertainty for data and models, and the role of salience. Salience provides a communication tool for discussing the importance of a particular data set for a specific model.

In the end, we think that we reached a consensus that parts of current British Columbia and other areas of the North American Cordillera were translated significant distances northward starting at ca. 90 Ma.

Encourage the interest and future research of early career scientists. The scheduled activities were designed to encourage the engagement and interaction of early career scientists, both with senior researchers and among themselves. Multiple breakout group meetings were convened to discuss ideas and ask questions throughout the conference. The breakout groups—consisting of assigned participants from various career stages and different parts of the Cordillera—were viewed as particularly helpful. The breakout groups changed composition multiple times, giving participants the chance to engage with a variety of perspectives. The early career scientists reported on these breakout sessions, and they were also given the opportunity to ask questions first during the broader group discussions before opening questions to all participants. Finally, an evening event was held for early career scientists and students to get to know each other and to talk with senior participants who had taken various career paths (e.g., liberal arts college, major research university, state survey, working abroad, etc.), as well as an NSF program manager. We were able to fund this event, plus the registration and travel for most early career participants, from an NSF conference grant and funding from the Geological Society of America associated with holding a Penrose Conference.

Identify scientific questions that are important and tractable ("low-hanging fruit"). One of the tasks given to breakout groups was to think about key data sets that would provide some of the missing links in developing and finding consensus among a model for the Cretaceous–Eocene Cordillera development. Some major questions and suggestions for missing data sets arose from the conference, including the following:

- In the mantle tomography data sets, what does the slab wall under the east coast of North America represent?
- Better timing is needed for the docking of the Guerrero terrane to Mexico.
- Better constraints on the paleogeography and relationships between Guerrero and other North America terranes.
- More data is needed to understand the movement and the timing of the movement of the Carmacks Group along the Rocky Mountain trench.
- Where are the breaks between terranes that clearly translated northward versus those that did not?

These are just a few of many topics that were discussed during the conference. By the end of the week, many participants were discussing collaborative proposals and projects to better understand the Cordilleran tectonic history.

Find ways of moving forward as a community. The conference consisted of many discussions during breakout sessions, during poster sessions, after talks, and after panel discussions. The afternoon of the last conference day was dedicated to thinking about ways to keep these conversations going. Some events that have and will occur include:

- Sarah Roeske and Carla Eichler have taken the lead on an approximately biweekly seminar series on Zoom that is focused on North American Cordilleran tectonics. The goal of the Zoom series is to include as many participants as possible, knowing that traveling to conferences can be costly. All are welcome to join in on the Zoom series.
- A series of sessions at GSA Connects 2024 in Anaheim that will look at the tectonic history of the Cordilleran through time.
- A workshop to reconvene the group at the 2026 GSA Cordilleran Section Meeting in Loreto, Mexico.
- A paleomagnetism "what you need to know" short course at a future GSA Connects or Cordilleran Section Meeting.
- Developing a mechanism, such as a short course or webinar, to work as a community with GPlates, a software for the visualization of plate tectonics.
- A GSA Special Paper that will include papers that highlight the conference theme. We are still currently seeking papers for this volume, with a due date of 1 May 2024. Please email the Penrose leaders (basil@geology.wisc.edu; staciag@unr.edu) if you are interested in contributing.

BROADER IMPACT

The Penrose Conference also included a broader impact component, made possible by the participation of Nick Zentner. Nick recently finished a "Baja-BC A-to-Z" YouTube series, in which he had engaged an international community of the broader public (the self-proclaimed "Zentnerds") with the science and scientists studying the western margin of North America. The Penrose leaders led a two-day field trip in western Idaho for a group of ~80 Zentnerds immediately prior to the Penrose Conference, so they could experience a geology field trip and see some of the rocks that show evidence of dextral motion along the North American margin. During the Penrose Conference, Nick

Penrose participants enjoying one of the conference field trip stops in the western Idaho shear zone outside of McCall, Idaho.

made videos, interviewing participants during the field trips and hosting a livestream from one day of the conference. Nick also did a follow-up video that summarized the conference and its outcomes. Overall, Nick's presence was beneficial to his dedicated audience of Zentnerds, who had the chance to see how scientific conferences work and how science can move forward through group discussions. Nick's videos were also very beneficial to the Penrose participants, who saw a potential new way to share science effectively with the broader public.

Finally, we note that two active participants passed away prior to the meeting. Paul Umhoefer was a proposer of the original Penrose application and Robert Molina wrote a letter of support. Their presence was sorely missed, and the GSA Special Paper will be dedicated to these two great scientists.

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Leaders: Stacia Gordon (University of Nevada–Reno), Elena Centeno-García (UNAM), and Basil Tikoff (University of Wisconsin–Madison)

Participants: Matthew Aleksey, Christopher Alfonso, Chuck Bailey, Sarnav Bakshi, Elizabeth Balgord, Arturo Barron Díaz, Andrew Barth, Amar Jyoti Baruah, Mark Beaufait, Scott Bennett, Jeff Benowitz, Joseph Biasi, Ericka Boudreau, Daniel Brennan, Matt Brueseke, Robinson Cecil, Jay Chapman, Edward Clennett, Manuel Contreras-López, Darrel Cowan, Claire Currie, Michael Darin, Erin Donaghy, Carla Eichler, Elisa Fitz-Díaz, Megan Flansburg, George Gehrels, Christine Griffith, Luis Javier Gutiérrez-Trejo, Stephen Harlan, Bernie Housen, Eugene Humphreys, Stephen Johnston, Tim Lawton, Allen McGrew, Robert Miller, Elena Miranda, Rebecca Morris, Sean Mulcahy, Suzanne Mulligan, Rijumon Nandy, Ellen Nelson, Devon Orme, Diego Alberto Osorio Afanador, Terry Pavlis, Dave Pearson, Daniel Quick, Anthony Ramírez-Salazar, Andrea Richardson, Ken Ridgway, Sarah Roeske, Margi Rusmore, Keegan Schmidt, Joshua Schwartz, Gabriel Serrano-López, Nikki Seymour, Jessie Shields, Karin Sigloch, Natalia Siqueiros-Moreno, Harold Stowell, Kathleen Surpless, Carolyn Tewksbury-Christle, Sarah Trevino, Nicholas Van Buer, Karissa Vermillion, Adolph Yonkee, Trevor Waldien, Jordan Wang, John Weber, Michael Wells, Jonny Wu, Sandra Wyld, and Nick Zentner

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