The National Academies of
SCIENCES • ENGINEERING • MEDICINE

COMMITTEE ON SOLID EARTH GEOPHYSICS

How Are Plates Made and Preserved?

October 27, 2021

OPEN SESSION MATERIALS

How Are Plates Made and Preserved?

Fall Event of the
Committee on Solid Earth Geophysics

Plate tectonics provides the overarching framework for understanding active plate boundary processes, such as earthquakes and volcanic eruptions, interpreting Earth's geologic record, and quantifying thermo-chemical exchange between Earth's surface and deep interior through geologic time. While the broad picture of plate tectonics has been understood since the early 1960s, fundamental questions remain regarding how tectonic plates form and remain intact, how localized deformation is accommodated between and within rigid plates, and the efficiency of plate tectonics over Earth's history.

This meeting brings together a diverse range of approaches for studying plate tectonics, including geophysical imaging, seismic and geodetic observations of deformation, field studies, laboratory experiments, and numerical modeling. Key topics to explore include how oceanic and continental plates form and evolve, the internal structure of lithospheric plates and the lithosphere-asthenosphere boundary, and the processes that cause plate boundaries to localize. These topics are particularly timely given recent initiatives focusing on plate tectonic processes, including Pacific Array, Rift2Ridge, and SZ4D.

Register Here

Wednesday, October 27, 2021
All Times ET

12:00 PM	**Welcome and Introductions** *Mark Behn, COSEG Member*
12:15 PM	**What Puts the "Plate" in Plate Tectonics?** *Karen Fischer, Brown University*
1:00 PM	**BREAK**
1:05 PM	**Panel I: Plate Structure** *Moderator: Jeff Freymueller, COSEG Member*
	An Ocean-Bottom View of the Oceanic Lithosphere-Asthenosphere System *Jim Gaherty, Northern Arizona University* **Structure and Composition of Continental Lithosphere from Magnetotellurics and Seismics** *Kate Selway, University of South Australia* **Breaking up Continental Lithosphere is Hard to Do: Who's the Enabler, Magma or Tectonic Memory?** *Estella Atekwana, University of California, Davis* **Panel Discussion** *All speakers*
2:30 PM	**BREAK**

2:45 PM	**Panel II: How Are Plates Made and How Do They Evolve?** *Moderator: Jessica Warren, COSEG Member*
	Microphysics of Shear Localization and Weakening at Tectonic Plate Boundaries *Elvira Mulyukova, Northwestern University* **The Generation of Plates from a Thermal Boundary Layer: The Influence of a Spherical Geometry** *Julian Lowman, University of Toronto Scarborough* **Geological and Laboratory Constraints on the Microphysics of Ductile Shear Zones** *Phil Skemer, Washington University in St. Louis* **Panel Discussion** *All speakers*
4:10 PM	**BREAK**
4:15 PM	**Integrated Perspectives on the Rheology and Structure of the Lithosphere** *Greg Hirth, Brown University*
4:45 PM	**Concluding Remarks** *Donna Shillington, COSEG Member*
ADJOURN OPEN SESSION 4:50 PM	

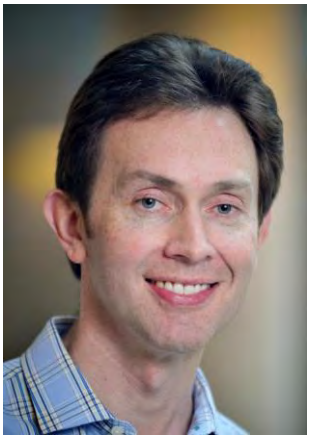
SPEAKER BIOS

Estella A. Atekwana is Dean of the College of Letters and Science and Professor of Earth & Planetary Science at the University of California, Davis. She was previously Dean of the College of Earth, Ocean & Environment at the University of Delaware. Her research focus is on biogeophysics, which investigates geophysical signatures of microbial-rock interactions. Dr. Atekwana is also known for her contributions to East African Rift tectonics. Here, she integrates geophysical imaging of shallow basin structures and lithospheric and upper mantle structures to understand the geodynamic processes of continental rift initiation and how preexisting Precambrian structures modulate strain localization. She is a champion for developing a diverse talent pool in STEM and capacity building in developing countries. Dr. Atekwana is the recipient of the Society of Exploration Geophysicists (SEG) 2021 Reginald Fessenden Award, 2020 SEG Near Surface Geophysics Global Virtual Lecturer, 2019 Association for Women Geoscientists Outstanding Educator, the 2016 SEG Outstanding Educator award, and numerous best paper awards. She is a Fellow of the Geological Society of America. She is a member of the U.S. National Committee for the International Union of Geological Sciences and also of the Board on Earth Sciences and Resources of the National Academies of Sciences, Engineering, and Medicine. She currently serves as Editor of American Geophysical Union (AGU) Books and Associate Editor of the *Journal of Geophysical Research-Biogeosciences*. She is a member of the College of Fellows committee, advisory board member of AGU LANDInG, AGU H&R committees, and the SEG Justice, Equity, Diversity and Inclusion committee. She is a member of the AGU, Geological Society of America, SEG, National Association of Black Geoscientists, Geochemical Society, and European Association of Geoscientists and Engineers. Dr. Atekwana received her B.S. and M.S. in Geology from Howard University and her Ph.D. in Geophysics from Dalhousie University in Halifax, Nova Scotia, Canada.

Karen M. Fischer is the Louis and Elizabeth Scherck Distinguished Professor of Geological Sciences at Brown University. A seismologist who studies the structure and dynamics of Earth's interior, her work focuses on understanding the lithosphere and asthenosphere, how these layers are created, deform and evolve over time, and their roles in plate tectonics and mantle convection. Dr. Fischer is a Fellow of the American Geophysical Union (AGU) and is the recipient of the Harry Fielding Reid Medal from the Seismological Society of America. She served as the President of the AGU Seismology Section, and she presented the 2016 AGU Beno Gutenberg Lecture. At Brown, her work has been recognized with the Royce Family Professorship in Teaching Excellence and the Karen T. Romer Award for Undergraduate Advising and Mentoring. She earned her B.S. in Geology and Geophysics from Yale University, her Ph.D. in Geophysics from the Massachusetts Institute of Technology, and was a Postdoctoral Fellow at the Lamont Doherty Earth Observatory of Columbia University.

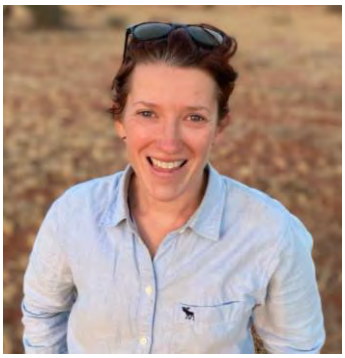
James Gaherty is a Professor of Geophysics in the School of Earth and Sustainability at Northern Arizona University (NAU). He utilizes seismic imaging tools to probe the major tectonic processes shaping Earth's surface, from continental rifting in east Africa to subduction off of the western U.S. to mantle convection beneath the Pacific basin. His approach is centered on deploying cutting-edge seismic field equipment to target critical dynamic processes, and he has lead ten major field investigations on three continents and two of the world's ocean basins. In many cases, this approach not only enables a focused look at earthquakes and associated deformation processes but also provides opportunities for capacity building and outreach in the communities within which he works. Dr. Gaherty has held several community leadership positions within the Incorporated Research Institutions for Seismology (IRIS), including Vice-Chair of the Board of Directors and has served as associated editor for journals of the American Geophysical Union (G-cubed) and the American Association for the Advancement of Science (*Science Advances*). He currently supports the National Science Foundation funded Ocean Bottom Seismograph Instrument Center as Chair of their community-based operations committee. Prior to joining NAU in 2020, Dr. Gaherty served on the scientific staff of the Lamont-Doherty Earth Observatory of Columbia University and as an Assistant Professor at Georgia Institute of Technology. He received his B.S. in Geology-Physics/Math from Brown University, his M.S. in Geology from the University of Michigan, and his Ph.D. in Geophysics from the Massachusetts Institute of Technology.

Greg Hirth is a professor in the Department of Earth, Environmental and Planetary Sciences at Brown University. He studies experimental rock mechanics, deformation mechanisms, and frictional properties in both crustal and mantle lithologies, structural geology, and the application of lab data to geophysical and geological problems. He focuses on the processes that control the mechanical behavior of rocks using optical and electron microscopy in conjunction with theoretical considerations. Previously, he spent 14 years as a research scientist at the Woods Hole Oceanographic Institution. Dr. Hirth was honored with the Geological Society of America's George P. Woollard Award in 2018 and presented the American Geophysical Union's (AGU) Francis Birch Lecture in 2017. He is a Fellow of the Mineralogical Society of America and the AGU. He received his B.S. in Geological Sciences from Indiana University, his Sc.B. and Ph.D. in Geological Sciences from Brown University, and completed two years as a Postdoctoral Researcher at the University of Minnesota.

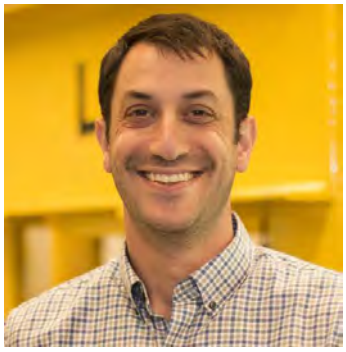


Julian Lowman is a physics professor at the University of Toronto Scarborough. He is a geodynamicist whose work focuses on numerical modeling of the thermal evolution of planetary interiors, the influence of continents on the Earth's deep interior, and numerical methods in thermochemical flows. His research implements high performance computing and 3D visualization methods in the modeling of mantle convection and plate tectonics. Previously, Dr. Lowman was a lecturer in Earth Sciences at the University of Leeds following two years as a postdoctoral researcher at Los Alamos National Laboratory. He is the current President of the Canadian Geophysical Union. He received a B.Sc. in Physics and Mathematics from the University of Toronto and a Ph.D. in Earth and Space Science from York University, Canada.

Elvira Mulyukova is an assistant professor in the Department of Earth and Planetary Sciences at Weinberg College of Arts & Sciences, Northwestern University. Previously, she was a research scientist at Yale University. Her research aims at understanding the physical processes that govern evolution of terrestrial planets, ranging from the atomic scale physics of mineral grains to the planetary scale of mantle flow. Dr. Mulyukova uses mathematical methods to develop physically consistent models of rock mechanics and incorporates them into larger scale geodynamic models of plate tectonics, earthquake cycles, and other geological processes that shape the history and the future of rocky planets. She received her B.S. in Physics and M.S. in Physics of Geological Processes from the University of Oslo and her Ph.D. in Geophysics, Geodynamic Modelling at the University of Potsdam, which was based on the work she did at GFZ German Research Centre for Geosciences. She also completed a 2-year postdoctoral scholarship at Yale University.



Kate Selway is a Senior Research Fellow at the Future Industries Institute at the University of South Australia. A geophysicist and a specialist in the magnetotelluric method, her research is focused on developing our understanding of the lithosphere and asthensophere, particularly through combining geophysical and geochemical data. She received her B.S.(Hons) and Ph.D. in Geology and Geophysics from the University of Adelaide and has subsequently held postdoc and fellowship positions at Yale, Lamont-Doherty Earth Observatory, the University of Oslo, and Macquarie University.



Phil Skemer is Professor of Earth and Planetary Sciences at Washington University in St. Louis. Dr. Skemer is a rock physicist, who uses laboratory based experiments to understand grain-scale deformation processes in geologic materials. A particular interest is the evolution of deformation microstructures at large strains and how these data help to explain rock rheology at plate boundaries. He received his B.A. in Geology from Pomona College and his M.Phil. and Ph.D. from Yale University. Following a two year postdoc at Brown University, he joined the faculty at Washington University in St. Louis, where he has been since 2009.

COSEG Statement of Task

The Committee on Solid Earth Geophysics (COSEG) provides independent advice to all levels of government and society on scientific, technical, and policy matters related to seismology, geodesy, and geodynamics.

Members are drawn from the public, academic, and private sectors and have a broad range of expertise and experience. The mission of the committee is as follows:

- To foster and encourage understanding of the structure, dynamics, and evolution of the Earth.
- To review and define basic and applied research activities in seismology, geodesy and geodynamics that contribute to federal agency missions.
- To address the transfer of seismological and geodynamics knowledge to areas of public welfare and national need including topics such as earthquake science; geological hazards; energy, mineral, and water resources; national security, global climate change; land-use planning; and public education.
- To foster long-term national efforts to collect, store and openly disseminate seismological, geodetic, and geodynamical data of all types.
- To foster long-term national efforts to monitor geodynamical events as well as nuclear testing treaties using geophysical technologies.
- To serve as the U.S. member of the International Lithosphere Program.

COSEG, formerly the Committee on Seismology and Geodynamics (name changed June 2020), was formed in 2001 as a standing committee of the Board on Earth Sciences and Resources. This committee succeeded three former entities: the Committee on Seismology, the U.S. Geodynamics Committee, and the Committee on Geodesy.

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COMMITTEE ON SOLID EARTH GEOPHYSICS
Board on Earth Sciences and Resources
Division on Earth and Life Studies

Biographical Sketches

Updated October 21, 2021

THORSTEN W. BECKER, Chair, is the Shell Foundation Distinguished Chair in Geophysics at the Institute for Geophysics and the Department of Geological Sciences, Jackson School of Geosciences, and a faculty associate at the Oden Institute for Computational Engineering & Sciences at The University of Texas at Austin. His main research interests are in geodynamics and seismology with a focus on interactions between mantle convection and surface tectonics—studying the inner workings of terrestrial planets and how their mantle and surface systems have co-evolved over time. He combines field, laboratory, and numerical approaches into dynamical models, focusing on the physics of plate tectonics from grain-scale deformation to plate-scale flow. He has co-authored more than 140 publications and is a Fellow of the American Geophysical Union. Dr. Becker holds an M.Sc. in physics from J. W. Goethe University, a Ph.D. in geophysics from Harvard University, and was a postdoctoral scholar at the Scripps Institution of Oceanography at the University of California, San Diego.

MARK D. BEHN is an associate professor in the Morrissey College of Arts and Sciences at Boston College. Dr. Behn's research investigates the dynamics of Earth deformation in glacial, marine, and terrestrial environments through the use of a wide range of geophysical techniques. These techniques include the development of geodynamic models that relate laboratory-based rheologic and petrologic models to the large-scale behavior of the Earth, which are then applied to a spectrum of problems from basic science to societally-relevant issues. His research interests include dynamics of faulting, magmatism, and surface processes at mid-ocean ridges and continental rifts; seismic anisotropy and imaging of sub-asthenospheric mantle flow; evolution of the continental crust; and ice-sheet dynamics. He is the co-chair of the Geodynamics Focus Research Group for the Community Surface Dynamics Modeling System, was active in the MARGINS/GeoPRISMS program, and is a former fellow of the WHOI Deep Ocean Exploration Institute. Dr. Behn received his B.S. in geology from Bates College and a Ph.D. in marine geophysics from the Massachusetts Institute of Technology/WHOI Joint Program.

JEFFREY T. FREYMUELLER is the Thomas A. Vogel Endowed Chair for Geology of the Solid Earth in the Department of Earth and Environmental Sciences at Michigan State University. Dr. Freymueller is an internationally recognized leader in the field of geodesy and utilizes satellites from the Global Positioning System (GPS) to make highly precise measurements of movement on the Earth's surface. In his far-reaching research activities, he has made discoveries in a wide range of topics including plate tectonics and plate boundary zones, faults dynamics, the continuing rebound of the Earth's surface from the melting of ice-age glaciers, inflation and deflation of volcanoes, and interpreting how changing water and ice levels

deform the Earth. He is particularly well-cited for his work on using GPS to understand the crustal deformation in China related to the formation of the Himalayas and the Tibetan Plateau. In addition to his research, Dr. Freymueller is the director of the EarthScope National Office. EarthScope is a long-term, large-scale program funded by the National Science Foundation to study the structure and evolution of North America and associated hazards through the deployment of thousands of geophysical instruments throughout the country. Dr. Freymueller also has served the scientific community as the U.S. National Correspondent to the International Association of Geodesy and its representative to the International Union of Geodesy and Geophysics, has served terms as an associate editor for the Journal of Geophysical Research and the Journal of Geodesy, and is currently Editor in Chief of the International Association of Geodesy Symposia Series. Dr. Freymueller received his M.S. and Ph.D. in geophysics from the University of South Carolina.

RENGIN GOK is a research seismologist at the Lawrence Livermore National Laboratory where she manages the Seismic Cooperation Program for the DOE/NNSA Office of Nuclear Verification. She is an expert in the development and improvement of seismic monitoring in international communities. Her interests include: seismic source behavior, Comprehensive Nuclear-Test-Ban Treaty verification technologies, velocity and attenuation structure of the Earth, and seismic hazard assessment and its engineering applications. She has published more than 35 peer-reviewed scientific papers. Dr. Gok earned her B.Sc. in geophysical engineering from Istanbul Technical University, and her M.Sc. and Ph.D. in geophysics from Bogazici University in Istanbul, Turkey.

DIEGO MELGAR is an assistant professor of geophysics in the Department of Earth Sciences at the University of Oregon where his research focuses on large earthquakes. He works on the physics of the rupture process and how to best image it by using many diverse kinds of on-shore and off-shore geophysical data. He also researches the hazards associated with these large events, working on tsunami modeling and coastal impacts, as well as studying how strong shaking is generated. Prior to joining the University of Oregon, Diego researched the role of global navigation satellite systems (GNSS) in seismology. He also spent three years at the University of California Berkeley's SeismoLab working on early warning systems. He continues to work on early warning systems to abate the societal impact of these hazards. Diego earned his B.Eng. in geophysics from the Universidad Nacional Autónoma de México and his M.S. and Ph.D. in geophysics from the Scripps Institution of Oceanography.

R. STEVEN NEREM is a professor in the Department of Aerospace Engineering Sciences and associate director of the Colorado Center for Astrodynamics Research at the University of Colorado at Boulder. Dr. Nerem's research interests include sea-level change, satellite altimetry, Earth's gravity field, planetary geodesy, precision orbit determination, and astrodynamics. He has served on two previous committees for the National Academies of Sciences, Engineering, and Medicine - the Committee on Earth Science and Applications from Space and the Committee on Evolving the Geodetic Infrastructure to Meet New Scientific Needs. Dr. Nerem is the recipient of numerous awards including the American Astronautical Society's Earth Science and Applications Award and the American Geophysical Union's (AGU) Geodesy Section Award. He is a fellow of the AGU. Dr. Nerem earned a B.S. in geology from Colorado State University and an M.S. and Ph.D. in aerospace engineering from the University of Texas, Austin.

DONNA J. SHILLINGTON is an associate professor in the School of Earth and Sustainability at Northern Arizona University. Her research focuses on deformation, magmatism, and sedimentation at plate tectonic boundaries and in other interesting geological settings, which she studies using active-source seismology together with other geophysical, geological, and geochemical approaches. An important component of her research is the acquisition and analysis of novel geophysical data on land and at sea; she has sailed on 18 research cruises around the world and also led major seismic data collection efforts on land. Her prior community service and leadership includes serving on the IRIS Board of Directors, the steering committees of GeoPRISMS and EarthScope and the Marine Seismic Research Oversight Committee; she currently serves on the steering committee of the SZ4D Research Coordination Network. Prior to joining Northern Arizona University, she was a research scientist and professor at Lamont-Doherty Earth Observatory of Columbia University and a postdoctoral research scientist and lecturer at the National Oceanography Centre in Southampton, UK. Dr. Shillington earned her B.S. in geology and A.B.J. in journalism from the University of Georgia and her Ph.D. in geophysics from the University of Wyoming.

JESSICA M. WARREN is an associate professor in the Department of Earth Sciences at the University of Delaware. Dr. Warren's research focuses on the rheology and geochemistry of the Earth's upper mantle. She has worked extensively on the localization of deformation at plate boundaries with a focus on the transform faults that offset the global mid-ocean ridge system. She has also worked on the constraints provided by naturally deformed samples for interpreting seismic anisotropy. Dr. Warren has participated in 14 field expeditions including on-land expeditions to the western United States and Oman Ophiolite and seagoing expeditions in the Pacific, Atlantic, and Indian Oceans. In 2019, she served as chief scientist on the R/V Atlantis for a large ocean bottom seismometer (OBS) and dredging campaign on Gofar transform fault. Dr. Warren serves on the GeoPRISMS steering committee, the In-Situ Rock Deformation Research Coordination Network (RCN) steering committee, and previously on the Physical Properties of Earth Materials steering committee. Outreach by Dr. Warren includes work to improve the quality and accessibility of Earth Science education with a focus on field learning and the graduate experience. Dr. Warren is a recipient of a NSF CAREER award, Stanford Terman Fellowship, and Carnegie Postdoctoral Fellowship. She holds a B.A. First Class, M.A., and M.Sci. in natural sciences from the University of Cambridge and a Ph.D. in geochemistry and geophysics from the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution Joint Program.

Past Meeting and Webinar Topics

- March 2021: Novel Geophysical Datasets for Environmental Applications: Moving from Discovering Signals to Societal Benefits
- November 2020: Solid Earth Science and Sea Level Change
- July 2020: Tracking Environmental Changes Due to COVID-19 Through Remote Sensing: A COSG Webinar
- April 2020: Enhancing Quantitative Capacity of Geoscience Programs
- February 2020: Evolving the Geodetic Infrastructure to Meet New Scientific Needs: Report Briefing (Webinar)
- October 2019: Beyond the Black Box: The Future of Machine Learning and Data-Intensive Computing in the Solid Earth Geosciences
- May 2019: New Opportunities to Study Tectonic Precursors
- November 2018: (Re)assessing Seismic Hazard across the United States
- June 2018: Seismic Hazards in Near- and Long-Term Nuclear Waste Storage and Legacy seismic data
- March 2018: Cascadia Megaquake: Part 3 – Earthquake Early Warning and Tsunami Modeling (Webinar)
- November 2017: Integrative Subduction Zone Science: Moving into the Next Decade
- August 2017: Cascadia Megaquake: Part 2 – Current Strategies to Mitigate Loss of Life (Webinar)
- May 2017: Cascadia Megaquake: Part 1 – Current Science on Earthquake Source and Related Hazards (Webinar)
- May 2017: Communicating the Value of Geoscience to Society
- November 2016: The Cascadia Subduction Zone: Science, Impacts, and Response
- April 2016: Collaborative Graduate Training Initiatives in High Performance Computing for the Solid Earth sciences
- October 2015: Geophysical Research Challenges Spanning the Coastal Zone
- May 2015: Check-in with agencies