Technical Report – SCEC award 22106 -
The 2022 Gordon Research Conference and Gordon Research Seminar on Rock Deformation

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Abstract
This grant supported travel and conference fees for participants in the 2022 Gordon Research Conference (GRC) and Gordon Research Seminar (GRS) on Rock Deformation. The theme of the conference was "Combining Laboratory Measurements with Observational Constraints to Understand Tectonic Processes", which focused on how to scale up observations from laboratory experiments to tectonic processes. Dan Faulkner (Univ. of Liverpool) was the GRC chair and Heather Savage (UC Santa Cruz) was the vice chair. The GRS was run by Carolyn Tewksbury-Christle and Taka Kanaya. The majority of the funds from this grant supported early career researchers.

Technical Report

1. Scientific Motivation for 2022 GRC Rock Deformation
This grant partially supported the 2022 Gordon Research Conference (GRC) on Rock Deformation, held at Bates College, Maine from August 9th to 14th, 2022, and the 4th Rock Deformation Gordon Research Seminar (GRS) that was held immediately prior to the GRC, August 8th to 9th, 2022. The GRS program is designed to provide opportunities for early-career scientists to get involved at the Frontiers of Science.

The Rock Deformation GRC series highlights the latest research and future trends in brittle and ductile rock mechanics and applications, with experimental, field, numerical, and theoretical contributions. The conference assesses our understanding of the nature and controls on rock strength, fracture, friction and ductile flow during induced and natural tectonic loading. The conference goal is to promote multi-disciplinary and multi-scale studies of coupling between thermal, chemical and mechanical forces in minerals, rocks and fluids. The impact of rock deformation research also has far-reaching socio-economic impact through: identification, assessment and mitigation of geohazards (earthquakes, landslides, and volcanic eruptions), effectiveness and environmental integrity of hydrocarbon extraction and geothermal energy resources, and reliability of underground storage facilities.

The theme for the 2022 conference was *"Combining Laboratory Measurements with Observational Constraints to Understand Tectonic Processes".* Forty years ago, small-scale laboratory experiments were used to constrain the strength of the lithosphere. These consisted of a simple view of brittle upper crustal deformation and viscous deformation dominating at greater depth. Over the years these models have been refined by further experimentation but also through observational constraints from seismology, field investigations, geodesy, microstructural studies, scientific drilling, and modelling. The models have provided the platform to understand a vast array of applications involving rock deformation such as earthquakes, volcanic hazard,

anthropogenic produced deformation (extraction from reservoirs, induced seismicity) as well as a holistic view of how our planet functions from the core to surface.

Laboratory measurements, coupled with a wide range of observations, have helped to determine the fundamental physics and chemistry of rock deformation at a very wide range of scales. Nonetheless, there is still enormous scope for interaction between those working in the laboratory and other fields that will facilitate a fundamental understanding of tectonic processes that are currently poorly understood. This meeting explored how laboratory experimentation continues to contribute to understanding large-scale processes and how the field may interface with others to tackle new and relevant problems occurring on all scales.

The 2022 GRC on Rock Deformation presented cutting-edge research that spans a wide range of methodologies and materials, over a variety of spatial and temporal scales, with an eye on developing an integrated perspective on rock deformation. Presentations covered brittle and ductile deformation, from microstructures to mantle rheology, bringing together different disciplines that will benefit from greater interaction. The conference drew together international experts at the forefronts of their fields, both early-career and senior investigators, enabling the free exchange of ideas. The collegial and open atmosphere of the GRC, combining programmed sessions and discussions, as well as opportunities for informal gatherings in the afternoons, evenings and during meals, provides a forum for scientists from different disciplines and different career stages to have free and detailed discussions together, while developing new cross-disciplinary collaborations in a range of research areas.

The invited speakers represented a mix of scientific disciplines, including rock physics, geology, geophysics, geomechanics, materials science, and engineering. The conference brought together a collection of junior and senior investigators at the forefront of their fields and provide opportunities for junior scientists and graduate students to present their work in poster format and exchange ideas with leaders in the field. The GRC was organized into 9 sessions including 1) Lithospheric Rheology from Small-Scale Experiments; 2) Fundamental Frictional Processes; 3) Earthquake Mechanics; 4) Fault Slip in Nature; 5) Early-Career Investigator Presentations; 6) Lower Crustal Dynamics; 7) Mantle Rheology; 8) Shallow Subduction Processes; and 9) Deeper Subduction Processes.

In conjunction with the GRC on Rock Deformation, the 4th Rock Deformation GRS took place immediately prior to the GRC. Chaired by two young investigators, Taka Kanaya (McGill Univ.) and Carolyn Tewksbury-Christle (Fort Lewis Univ.), the GRS had the related and complimentary theme: *"Integrating Rock Deformation Studies with Geophysics, Field Geology and Modeling".* This meeting challenged the simple, canonical view of the brittle upper crust and ductile lower crust and mantle and address important issues such as (1) upscaling lab-based relations to plate-scale processes (*e.g.*, size-dependence of fracture energy and characteristic frictional slip distance; calibrating lab-derived flow laws with constraints from active and exhumed ductile shear zones); 2) characterizing rheology of short-term lithospheric dynamics (*e.g.*, fundamental studies of transient deformation and application to post-seismic deformation; rheology and evolution of ductile shear zones; interactions of mantle dynamics, surface tectonics, and climate loading; planetary geodynamics); and 3) understanding systems with heterogeneous rheology at different length scales (*e.g.*, rate-and-state friction and asperity-scale plasticity; brittle

heterogeneities within a ductile shear zone). Investigating these challenges requires integration among experimentalists, field and structural geologists, seismologists, geodesists, and geodynamicists. The GRS is geared toward early career researchers and so graduate students, post- docs, and other scientists with comparable levels of experience and education will come together in a highly-stimulating and non-intimidating environment to discuss their current research and build informal networks with their peers that may lead to a lifetime of collaboration and scientific achievement. All of the GRS attendees participated in the following GRC. Since the inaugural GRS in 2014, GRS Rock Deformation has been an integral part of GRC Rock Deformation and a highly successful and popular program for young scientists in the field.

Broader Impacts

This grant supported several early career scientists to attend the GRS and GRC. The feedback of participants was extremely positive for all these meetings, and the GRS experience gave attendees much more confidence when attending the GRC. As an example, priority was given to early career participants to ask the first questions after presentations, to launch the following discussion.