Subduction Cycles and Deformation (SCD)

Sarah Penniston-Dorland, Univ of Maryland
GeoPRISMS:

- Is a **community-driven** science program aimed at understanding active processes along continental margins, through integrative approaches that span the shoreline.

- Is a vibrant **interdisciplinary** research community (look around!) and an intellectual incubator for collaborative research...

- Addresses **first-order questions** about Earth’s most active tectonic, mass transfer, and sedimentary systems - relevant to major geohazards that affect population centers, including large earthquakes, volcanic eruptions, tsunamis, and landslides.

- Is an NSF funding opportunity, based on a science plan developed by the community.

Photo: D. Rasmusse
SCD Key Questions

• What governs the size of great subduction zone earthquakes?

• How do subduction zones initiate?

• How does volatile release affect rheology?

• How are fluids and melts released and stored in a subduction system?

• What are the products of subduction?

• What feedbacks exist between surface processes and subduction mechanics?
SCD Primary Sites and Initiatives

Thematic Studies

- Theme 1: Identifying controls on fault slip behavior and deformation history
- Theme 2: Understanding mantle wedge dynamics
- Theme 3: Fore-arc to back-arc volatile fluxes
- Theme 4: Physical and chemical conditions and processes at depth
- Theme 5: Subduction initiation

Alaska and Aleutians
Cascadia
New Zealand
Subduction Cycles and Deformation (SCD)
Planning and Meetings

Jan, 2011: SCD Implementation (Bastrop, TX)
Sep, 2011: Alaska Primary Site Planning (Portland, OR)
Apr, 2012: Cascadia Primary Site Planning (Portland, OR)
Apr, 2013: New Zealand Primary Site Planning (Wellington, NZ)
Oct, 2015: SCD TEI (Redondo Beach, CA)

Photo credit: Emily Cooperdock
**Subduction Cycles and Deformation (SCD) Mini-workshops**

Dec, 2011: ExTerra: Understanding Convergent Margin Processes through studies of Exhumed Terranes, Integrating CRISP IODP drilling and 3D seismic study, Using Geoinformatics resources to explore the generation of convergent margin magmas

Dec, 2012: IODP Opportunities for SCD, Marine Geophysics in the Cascadia Primary Site

Aug, 2013: ExTerra: Understanding Subduction through studies of exhumed terranes

Dec, 2013: Kermadec Arc-Havre Trough Planning, Field Logistics for GeoPRISMS Research in the Aleutian Arc, Exploring the interplay between solid Earth tectonics and surface processes

Dec, 2014: Cultivate and coordinate GeoPRISMS studies of the Hikurangi subduction margin, South Island New Zealand Primary Site

Dec, 2015: Himalayan Seismogenic Zone

Dec, 2016: EarthScope-type Canadian Cordiller Seismic Array and GPS Network, Volcanoes in Extensional and Compressional Settings

Dec, 2017: Amphibious community experiments in Alaska and related opportunities

Dec, 2018: ExTerra: Evolution of arc crust; Investigating subduction processes at the Hikurangi Margin, New Zealand

Photo credit: Emily Cooperdock
Cascadia

RATIONALE
- Highly accessible for fieldwork, can leverage existing infrastructure and co-located research efforts
- Build on broad spectrum of existing geological and geophysical data
- A young, hot endmember subduction zone
- Well-suited for studying nature and origin of episodic tremor and slip (ETS)

Reduced upper mantle velocities near trench – hydration?

COMMUNITY EFFORTS
Cascadia Initiative (2009-2014) – community experiment - an onshore-offshore geophysical and geodetic project including deployment of the Amphibious Array.

Janiszewski et al., GJI, in press
Cascadia

COAST Cascadia Open Access Seismic Transects (2012) – acquired diverse geophysical data to achieve a variety of goals including constraining the position of & geometry of plate boundary.

Determine temperature along megathrust, quantify fluid fluxes, investigation of methane emissions.

- Flow meter
- Thermal blanket
- Heat flow probes
- Carbonate formation at methane emission site
Cascadia

Wave Glider

Constraining slip distribution of the Cascadia Subduction Zone Offshore (2012-2016) – use GPS-Acoustic seafloor geodesy to measure slip deficit offshore.

*iMUSH (2012-2016)*—image architecture of Mount St. Helens magmatic system from the subducted plate to surface using geophysical and petrological approaches

Kiser et al., 2016

Wanke et al., 2019

Wanke et al., 2019

Kiser et al., 2016
Alaska and Aleutian

RATIONALE

• Both ocean-ocean and ocean-continent boundaries
• Different modes of slip and different stages of earthquake cycle in segments, some locked, some creeping
• Leverage Plate Boundary Observatory, US Transportable Array & existing USGS work

Evolution of the chemically diverse Aleutian Arc

GeoPRISMS Data Portal

Geochemistry of volcanic fluids, Katmai

Dredging in the Aleutians
Alaska and Aleutian Community Efforts
Field Campaigns to the Aleutians (2015-2016)

Investigating older rocks in the oceanic Aleutian volcanic arc east of Adak

MT & seismic investigation of arc melt generation, delivery and storage beneath Okmok volcano

Islands of Four Mountains to Unimak: From the slab to the surface

Seeking the origins of continents in the western Aleutian island arc

Modeling sediment production from glaciers off south-central Alaska
Alaska and Aleutian

Alaska Amphibious Community Seismic Experiment (2018-2019) 75 broadband OBS, 30 land broadband sensors, covers incoming plate-megathrust-volcanic arc-distal backarc (even more when integrated with TA)

Links between structures (plate bend normal faults) in downgoing plate and hydration and seismicity in subduction zone

Li and Freymueller, 2018

Interseismic Slip Deficit at the Edge of a Locked Patch: Shumagin Islands, Alaska

Mapping the Alaska Megathrust

Shillington et al. 2015
New Zealand

RATIONALE

- Range of fault slip and volcanic phenomena with along-strike variation in small, compact setting
- Active subduction initiation (Puysegur Ridge), exhumed arc crust (Fiordland), seismogenic zone, sedimentation, & forearc deformation (Hikurangi Margin), arc volcanism (Taupo Volcanic Zone, Kermadec Arc), back-arc rifting (Taupo, Havre Trough)
- Government investments in onshore and offshore scientific infrastructure

COMMUNITY EFFORTS

NZ3D & IODP Drilling (2017-2019) – Seismic reflection study and ocean drilling of Hikurangi margin to understand controls on slow slip events.
New Zealand

**SISIE South Island Subduction Initiation Experiment (2018-2019)**
-collecting onshore and offshore geophysical data across Puysegur trench

**SHIRE Seismogenesis at Hikurangi Integrated Research Experiment** – Geophysical imaging, Paleoseismology & morphotectonics, and Numerical modeling to investigate megathrust behavior and controls on seismogenesis

Volatile cycling through the Hikurangi forearc, New Zealand

Assessing changes in the state of magma storage system over caldera-forming eruption cycles, Taupo
New Zealand


HOBITSS Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (2014-2015) – Ocean bottom pressure sensors (APGs) and seismometers deployed. First detailed view of seafloor deformation during SSE. SSEs occur on shallowest reaches of megathrust, within 2 km of seafloor

Wallace et al. 2016
Thematic studies

RATIONALE

• Thematic studies include broader research approaches than can be achieved at primary sites.

_E-FIRE ExTerra (Exhumed Terranes) Field Institute and Research Endeavor (2015-2021)_ Collect exhumed subduction-related rocks in the Western Alps to investigate geochemical cycling, fluid release, and rheology.

Modeling and laboratory experiments

Wilson et al., 2014

Naliboff et al., 2013

Proctor and Hirth, 2015

Kitajima & Saffer, 2012
GeoPRISMS SCD TEI

October, 2015
Redondo Beach, CA

~130 scientists
>50% Early Career
>40% Female

Community-driven
Interdisciplinary