Geodynamic Processes at Rifting and Subducting Margins

GeoPRISMS

RICE

GeoPRISMS: Amphibious Continental Margin Studies

GeoPRISMS Chair: Julia Morgan

Website: www.geoprisms.org

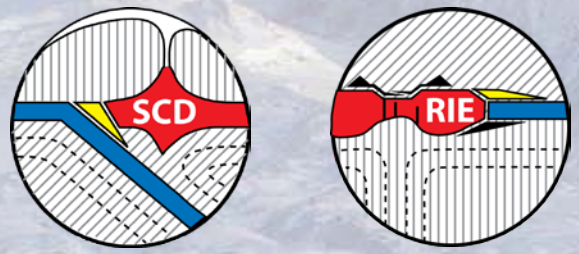
E-mail: info@geoprisms.org

... investigate the coupled geodynamics, earth surface processes, and climate interactions that build and modify continental margins *over a wide range of timescales (from s to My), and cross the shoreline, with applications to margin evolution & dynamics, construction of stratigraphic architecture, accumulation of economic resources, and associated geologic hazards and environmental management.*

GeoPRISMS – Successor to MARGINS

- **Focus on rifts and subduction zones**

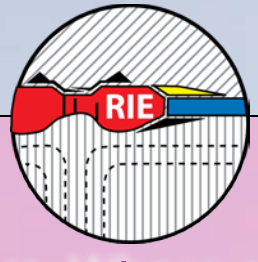
Subduction Cycles & Deformation



Rift Initiation & Evolution

- **Cross the shoreline (& NSF divisions)**
- **Integrate field, experimental, theory, modeling**
- **Primary sites & thematic studies**
- **Community building; communication, data access**
- **Leveraging opportunities & collaborations**

- **Facilities**
  - IRIS, EarthScope, UNAVCO
  - AAF, OBSIP
  - UNOLS, esp. Marcus Langseth
  - IODP, CDP
- **Partners & Communities**
  - IRIS, EarthScope, UNAVCO
  - USGS
  - IODP
  - International partners



GeoPRISMS Structure & Topics

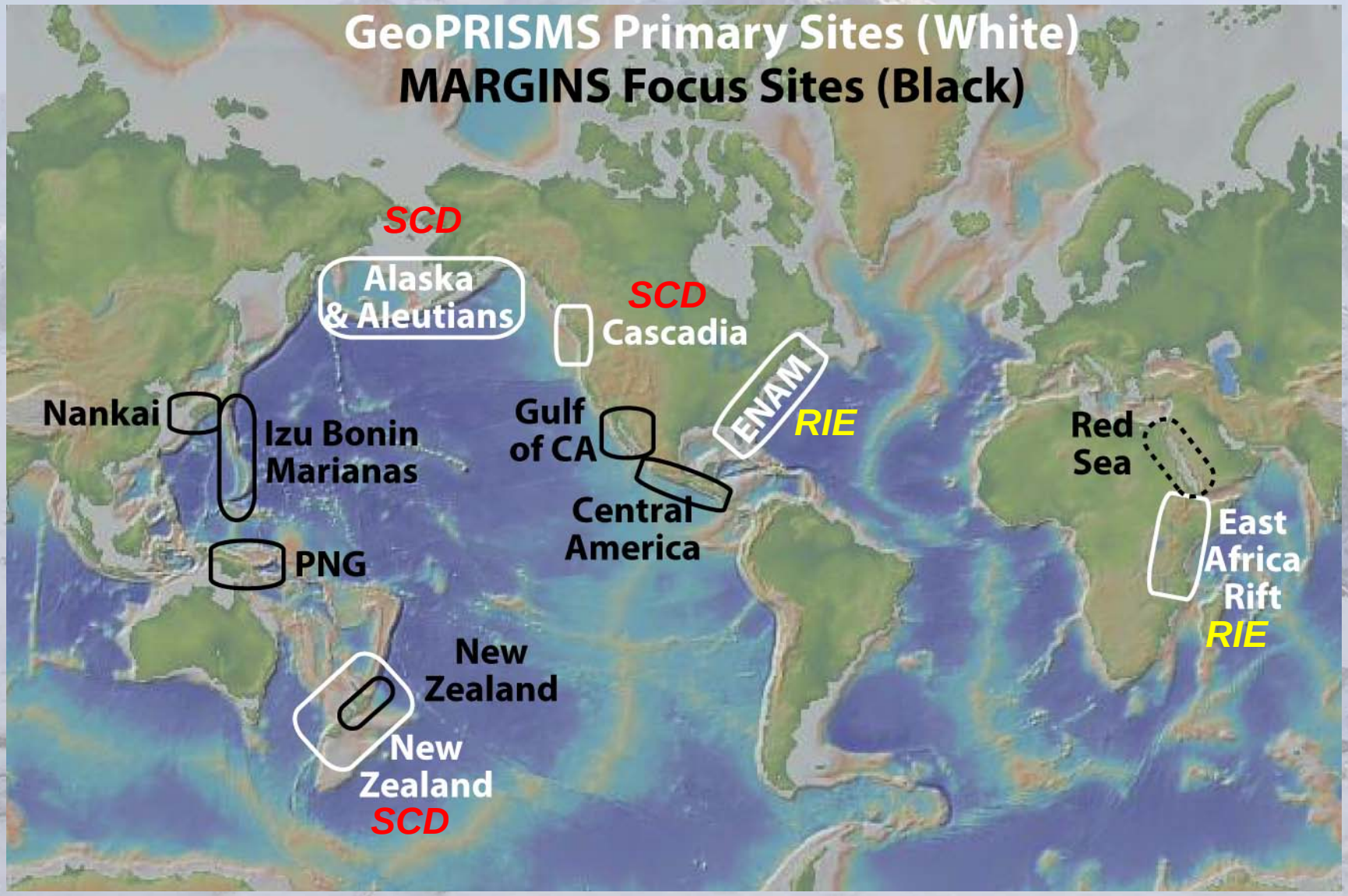
Rift Initiation and Evolution (RIE)

- Where and why continental rifts initiate
- Fundamental rifting processes; feedbacks in time & space
- Controls on the architecture of rifted continental margins
- Mechanisms & consequences of fluid & volatile exchange

Subduction Cycles and Deformation (SCD)

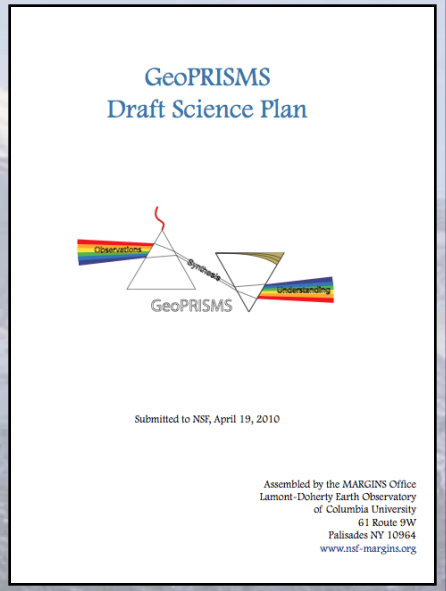
- Controls on size, frequency of earthquakes & slip behavior of subduction plate boundaries
- Spatial-temporal deformation patterns during the seismic cycle
- Linkages between volatiles & plate boundary rheology
- Volatile storage, transfer, & release in subduction systems
- Geochemical products of subduction; continent creation
- Subduction zone initiation and arc system formation
- Feedbacks between surface processes & subduction dynamics

Where GeoPRISMS Works

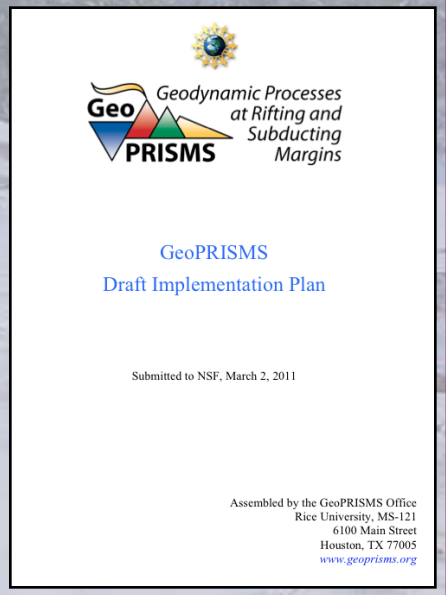


Role for Langseth in GeoPRISMS Science

- Meeting GeoPRISMS objectives offshore
  - Alaska-Aleutians Subduction Zone (AASZ)
  - Cascadia Subduction Zone (CSZ)
  - Eastern North American (ENAM)
  - New Zealand – Details TBA
- Complimenting onshore efforts to ensure **amphibious nature of program**

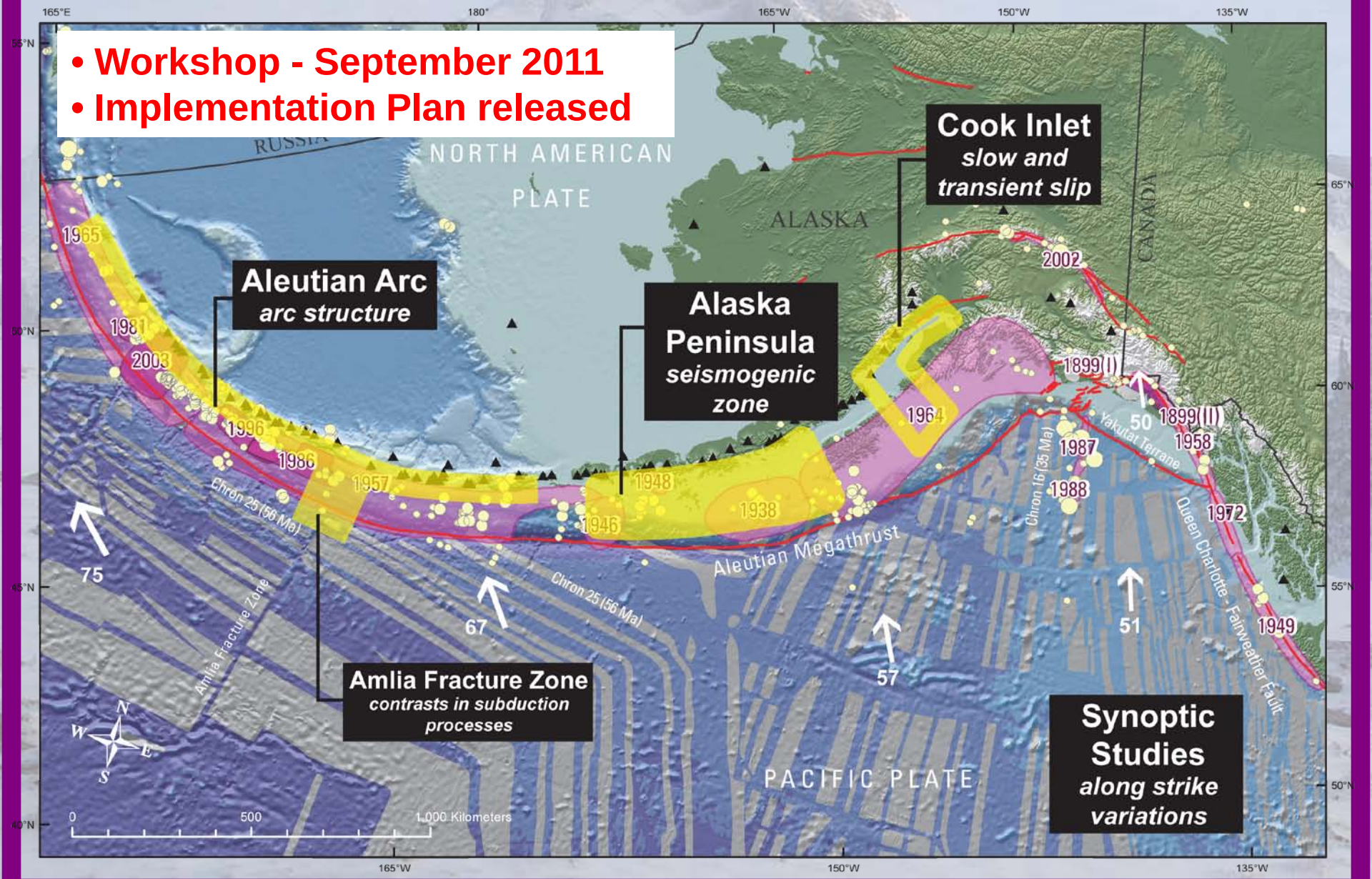


- **Marine seismic imaging is fundamental!**
  - **Crustal, lithosphere structure**
  - **Velocity structure, physical properties**
  - **Stratigraphic sequences**
  - **Site survey for future drilling**

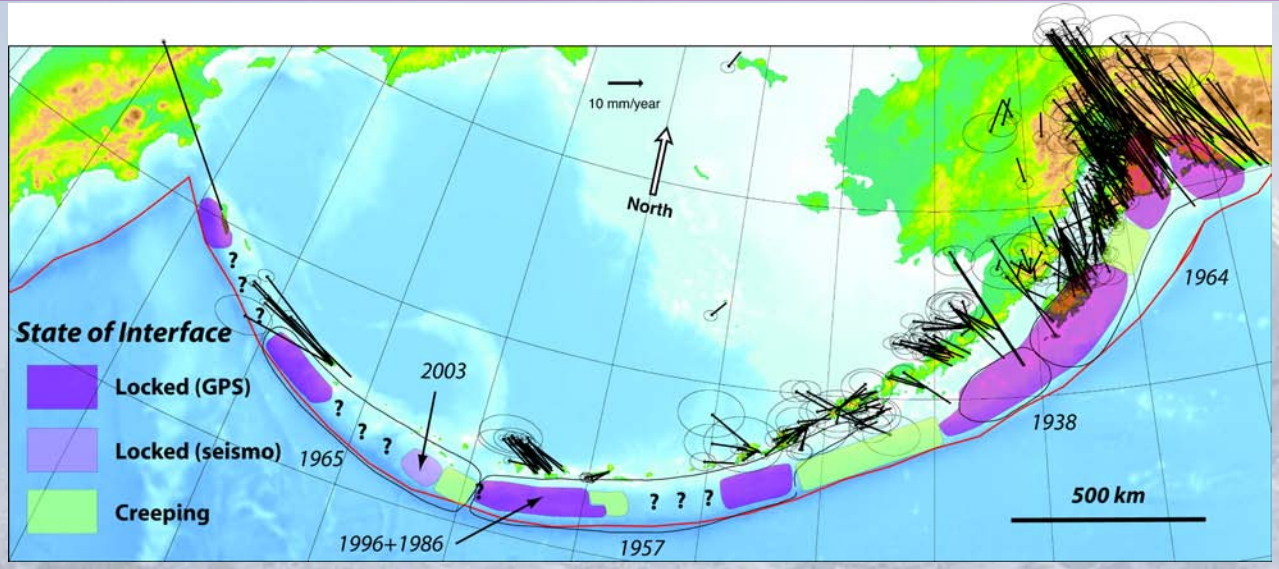


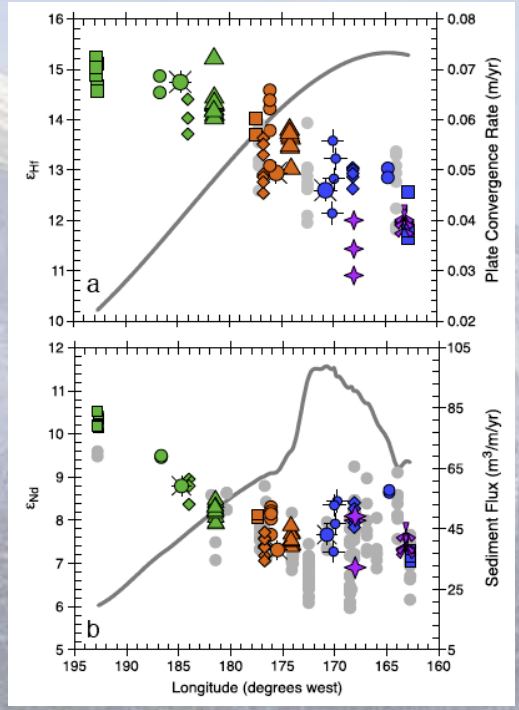
- Implementation Plans (IPs) outline scientific targets & research priorities

Alaska/Aleutians SZ Primary Site



Key Topics



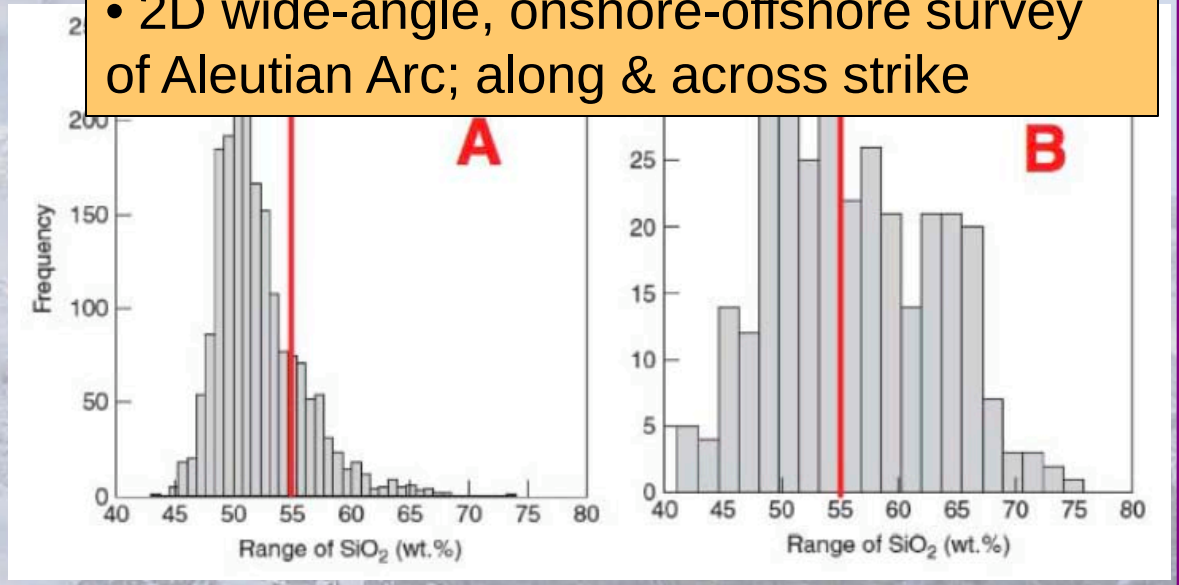


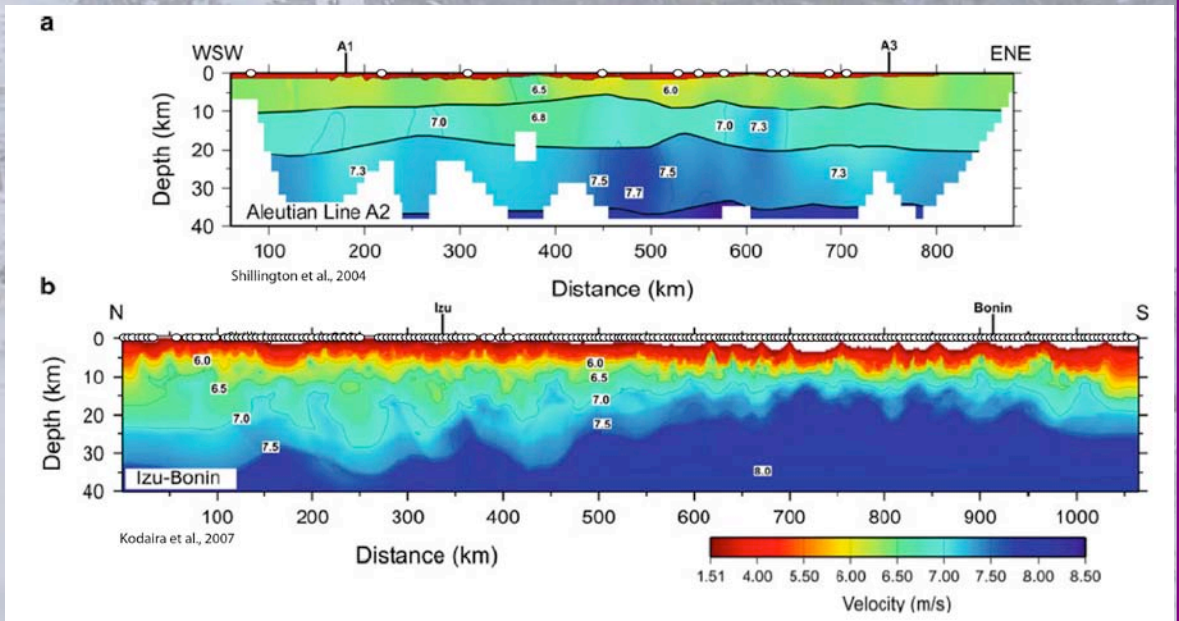
- *Along-strike variations in earthquake cycle*
- *Spectrum of fault behavior*
- *Long-term deformation and earthquake cycle*
- *Storage, transfer & release of volatiles, melts & fluids*
- *Geochemical products of subduction, creation of continental crust*
- *Shallow/crustal controls on volcanism*
- *Mass fluxes & the control on evolution and architecture of the subduction margin and effects on subduction dynamics*
- *Subduction initiation - Alaska Peninsula and the Aleutian Arc*

Aleutian Island Arc

- *Structure, history & composition of arc crust through volcanic and plutonic rocks*
- *Geophysical imaging of arc lithosphere.*
- *Storage, transfer, and release of volatiles through subduction*
- *Along-strike segmentation of the seismogenic zone across the Amlia fracture structure.*

• 2D wide-angle, onshore-offshore survey of Aleutian Arc; along & across strike





Alaska Peninsula

- *Processes controlling spatial & temporal patterns of megathrust earthquakes and extent of megathrust earthquake ruptures.*
- *Feedbacks betw. surface processes & subduction dynamics, e.g., how surface processes affect the forearc*
- *Role of sediment flux on arc seismicity and evolution.*

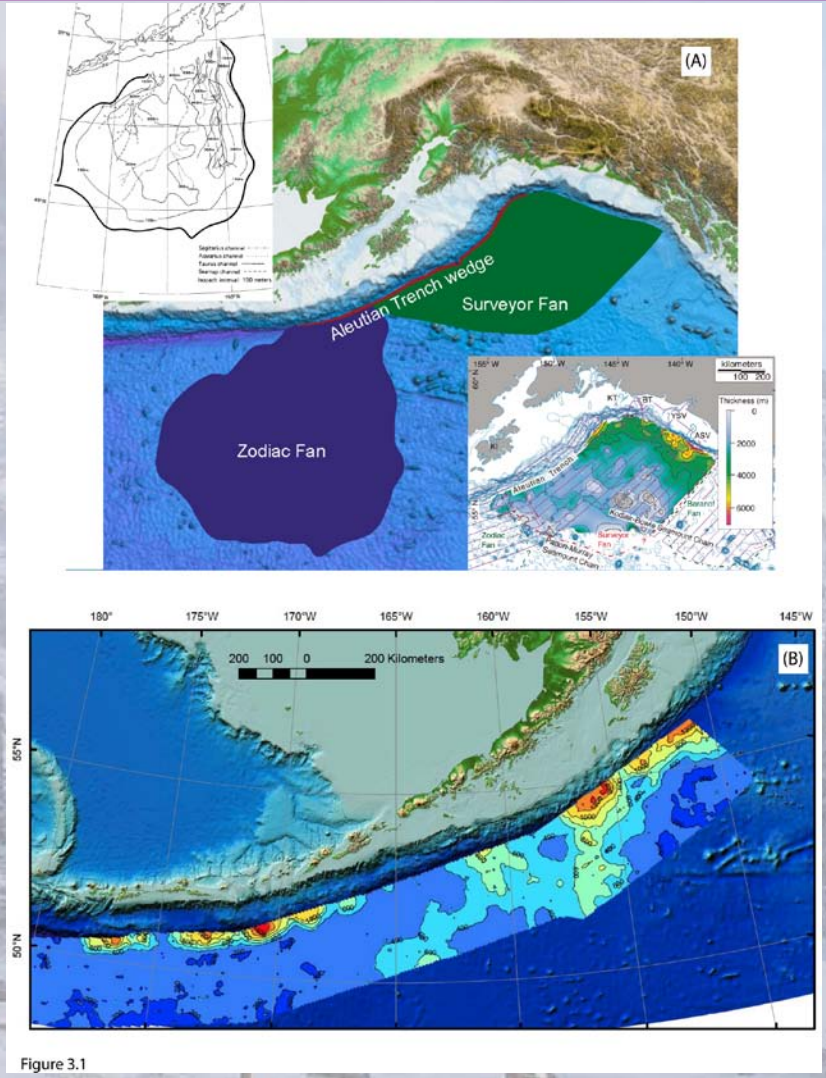
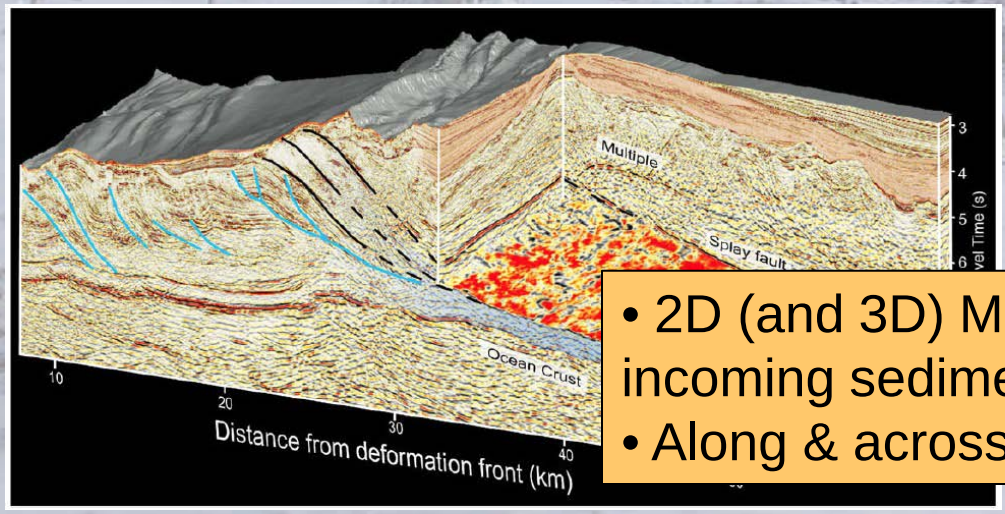


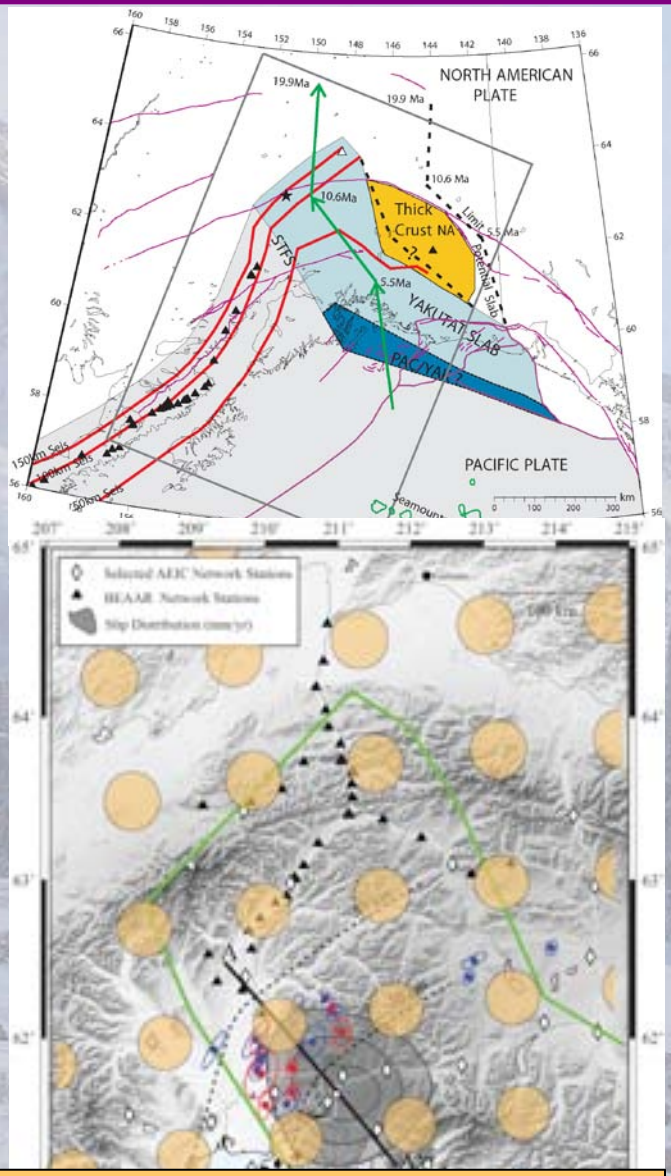
Figure 3.1



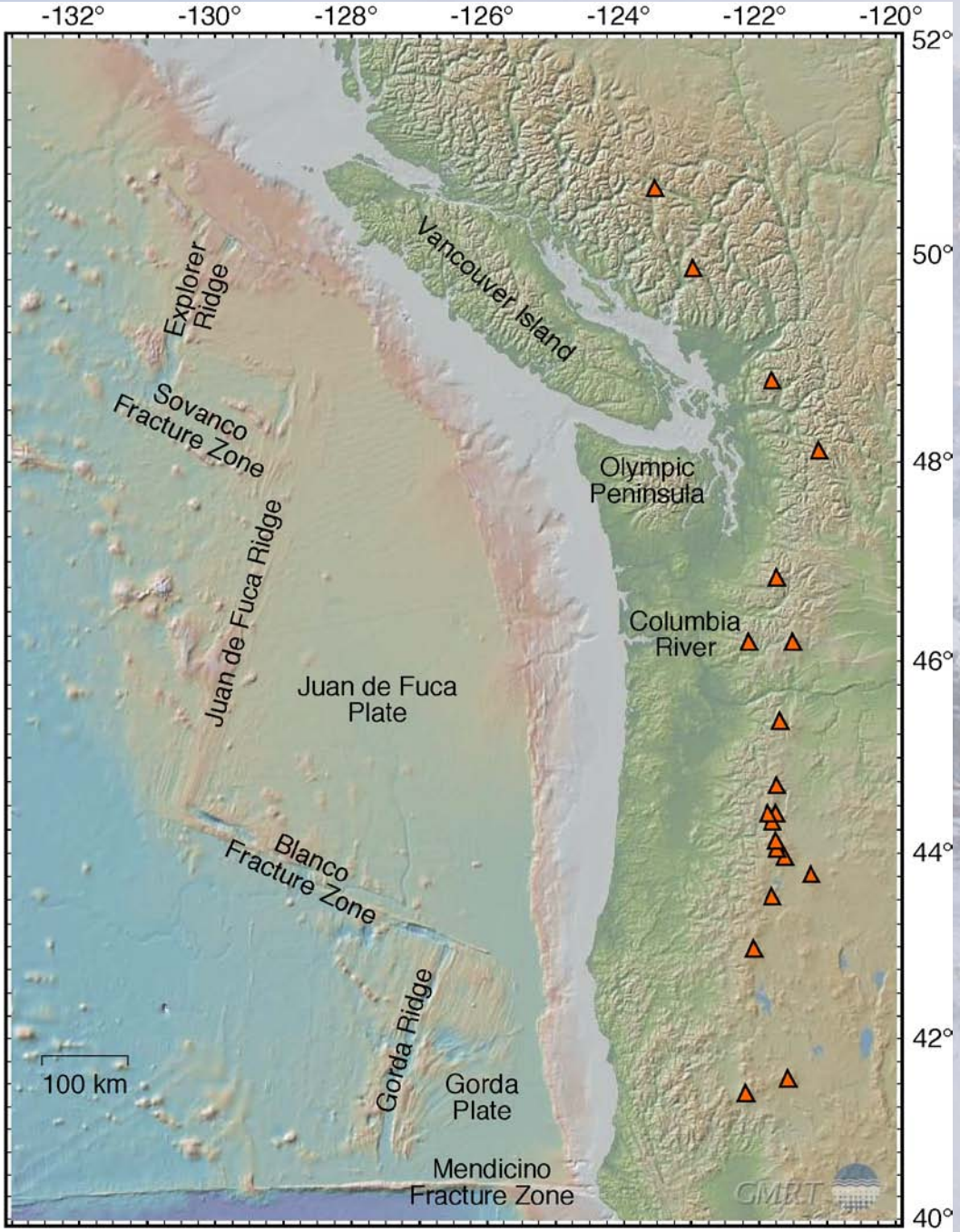
• 2D (and 3D) MCS surveys of megathrust, prism, incoming sediment, & plate
• Along & across strike variations in sediment flux

Cook Inlet

- *Rupture zone of 1964 M_W 9.2 earthquake*
- *Edge of Yakutat terrane*
- *Slip behavior of megathrust, in particular, large and small slow slip events and associated tremor, transient postseismic deformation*
- *Along-strike changes in the slip behavior at the edge of the Yakutat terrane.*
-
- *Opportunities for joint GeoPRISMS-EarthScope projects. and for leveraging EarthScope data.*



- 2D (and 3D) MCS surveys of megathrust properties, prism, incoming sediment, & plate
- Complementary to onshore studies; Yakutat collision



Cascadia Primary Site

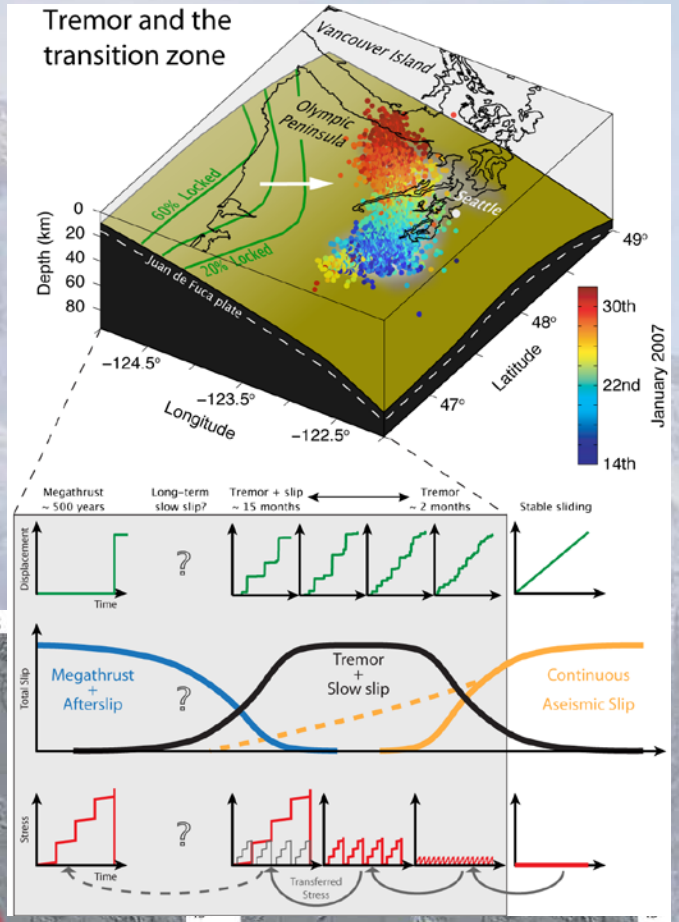
- Sediment accretion and subduction over time.
- Slow slip, tremor, great earthquakes, & megathrust conditions.
- Compositional diversity of Cascades volcanoes
- Explaining the Cascadia hot-slab paradox
- Role of volatiles in plate coupling
- Subduction initiation

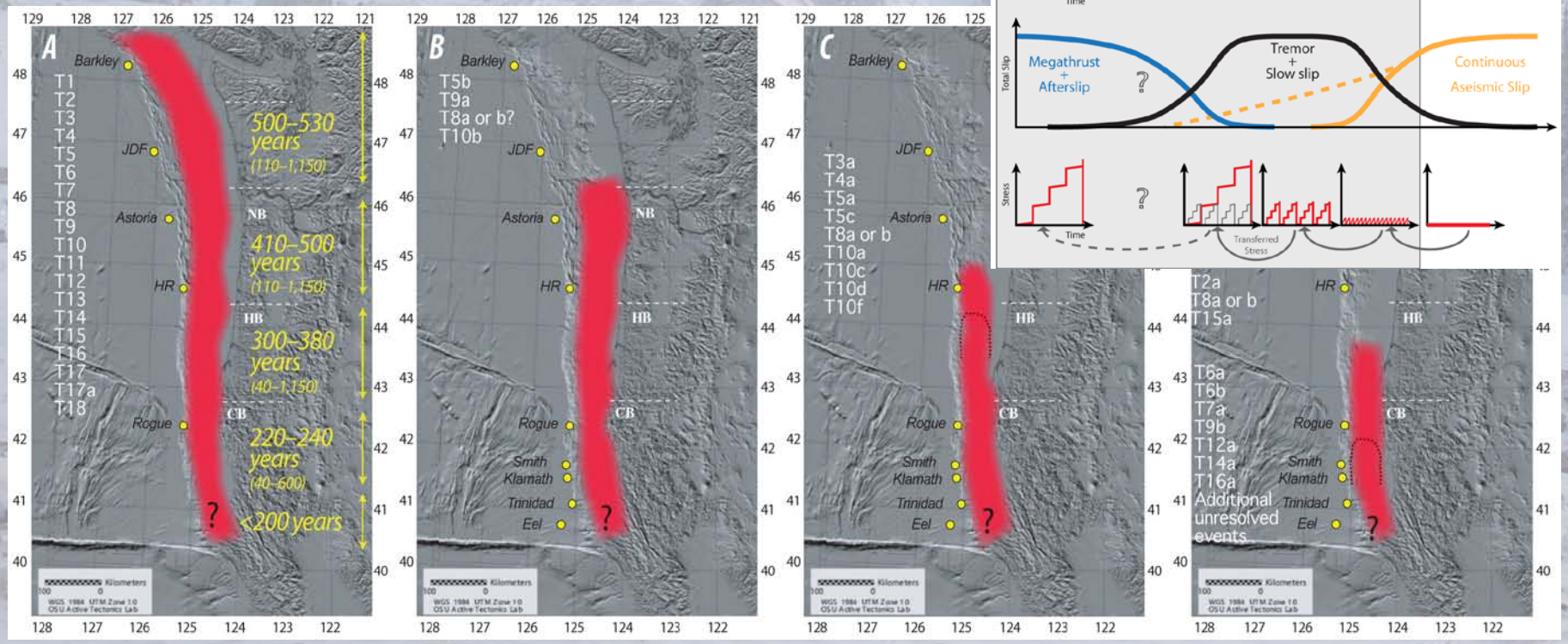
- **Workshop - April 2012**
- **Implem. Plan pending**

Megathrust Processes

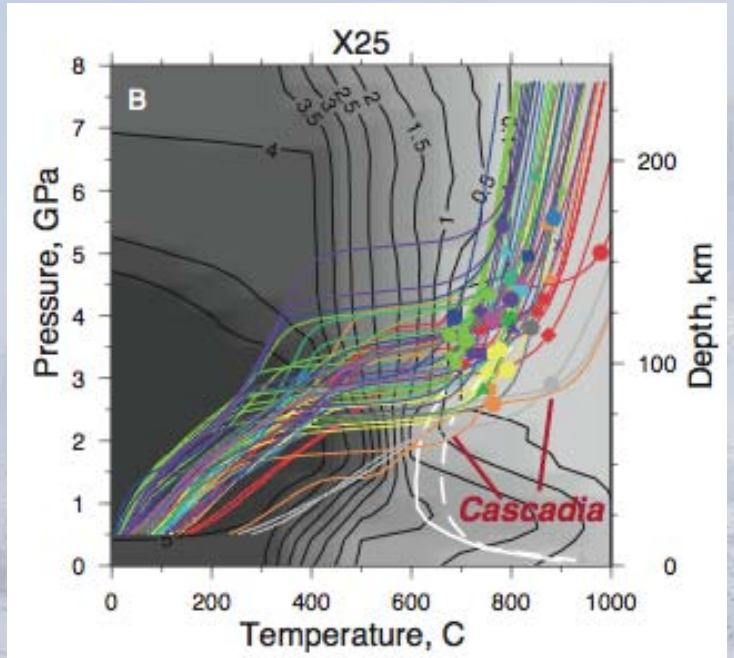
- *Capable of M9 earthquakes*
  - *Turbidite record, tsunami deposits*

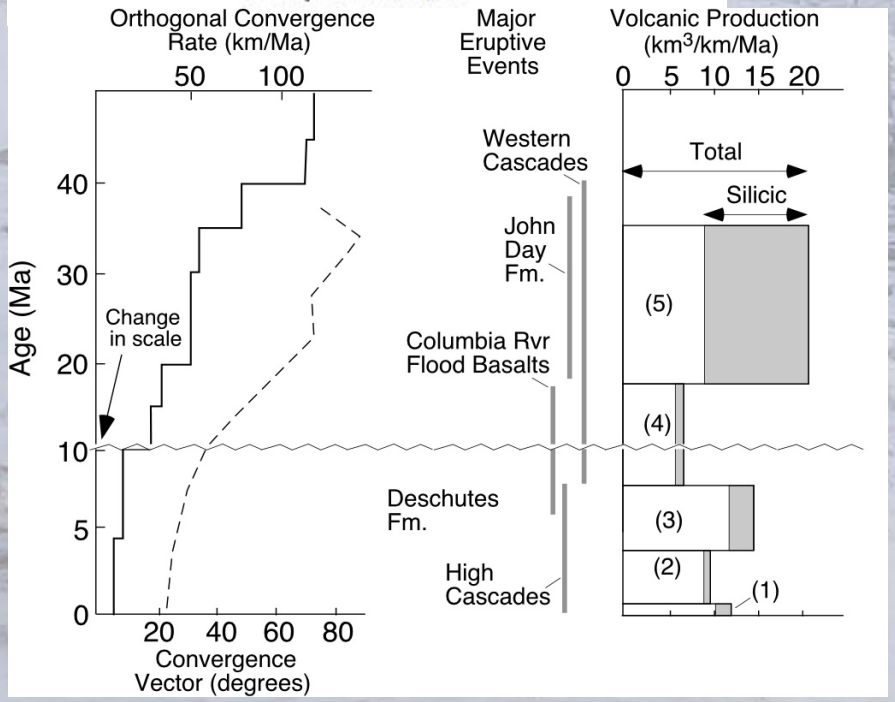
- *Well-documented slow-slip and tremor*
  - *Down-dip variations*
  - *Along-strike segmentation*





Geochemical Processes

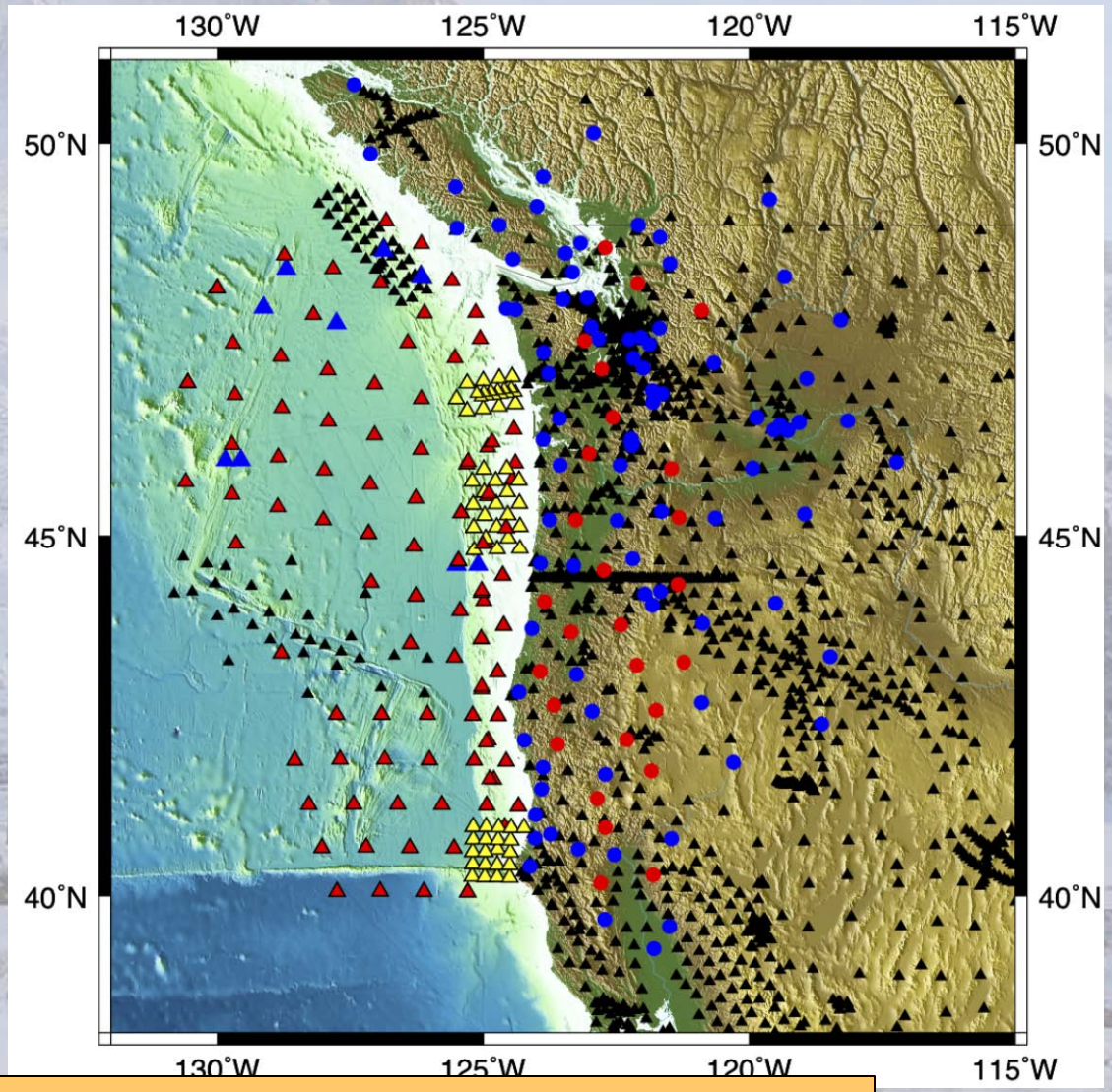




- *Hot subducting slab endmember, w/ implications*
  - *Volatile budget*
  - *Interplate slip behavior*
  - *Hot-slab paradox*
- *Temporal variations in volcanic output with convergence*
- *Along-strike variations in*
  - *Composition*
  - *Volcanic output*

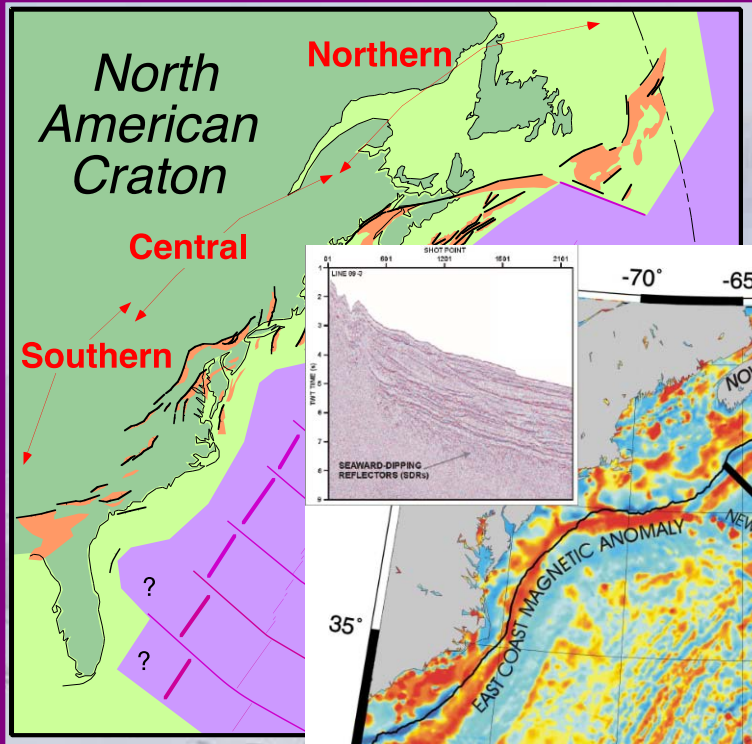
Cascadia Initiative & More

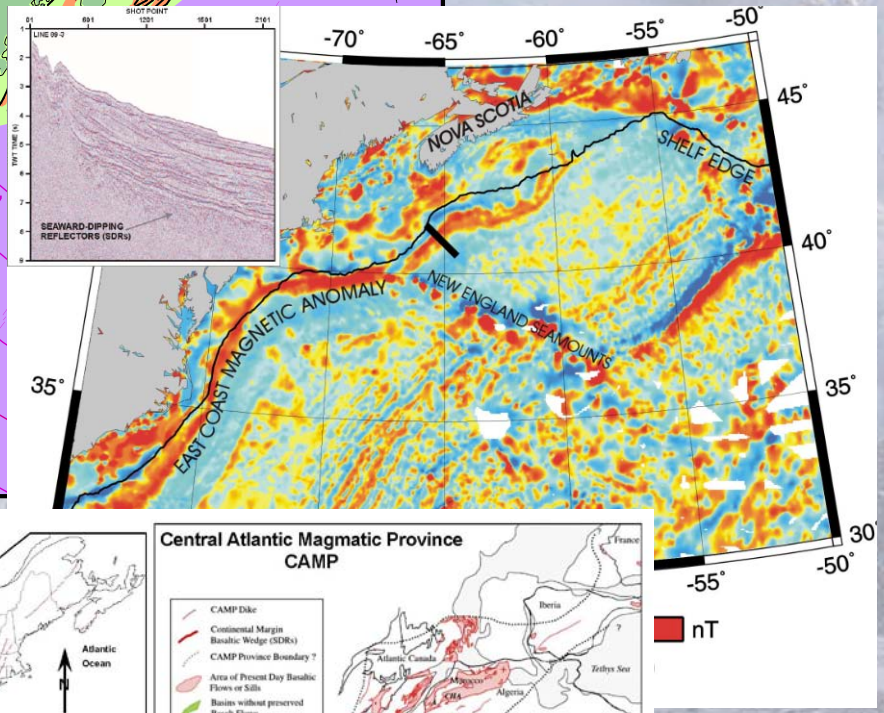
- CI - OBS deployments (through 2014),
- Earthscope deployments in Cascadia
  - TA (white)
  - FA: CAFÉ
  - FA: FACES
  - FA: High Lava Plains
  - FA: Mendocino
  - FA: SNEP
- NEPTUNE Canada
- SeaJade (2010, 2013)

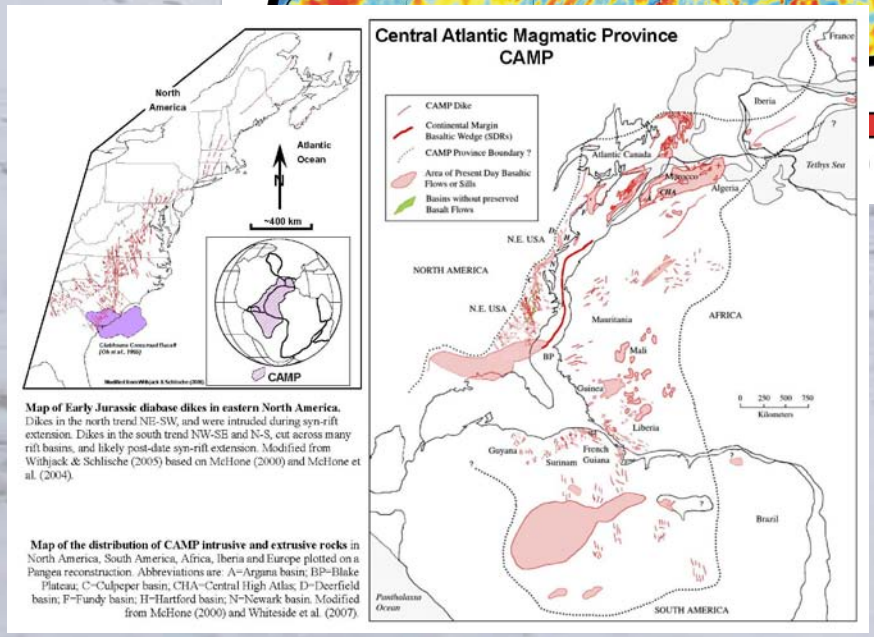


- 2D (& 3D) MCS-OBS surveys of megathrust interface, seismic properties, structural architecture of slabe and overriding plate

ENAM Primary Site







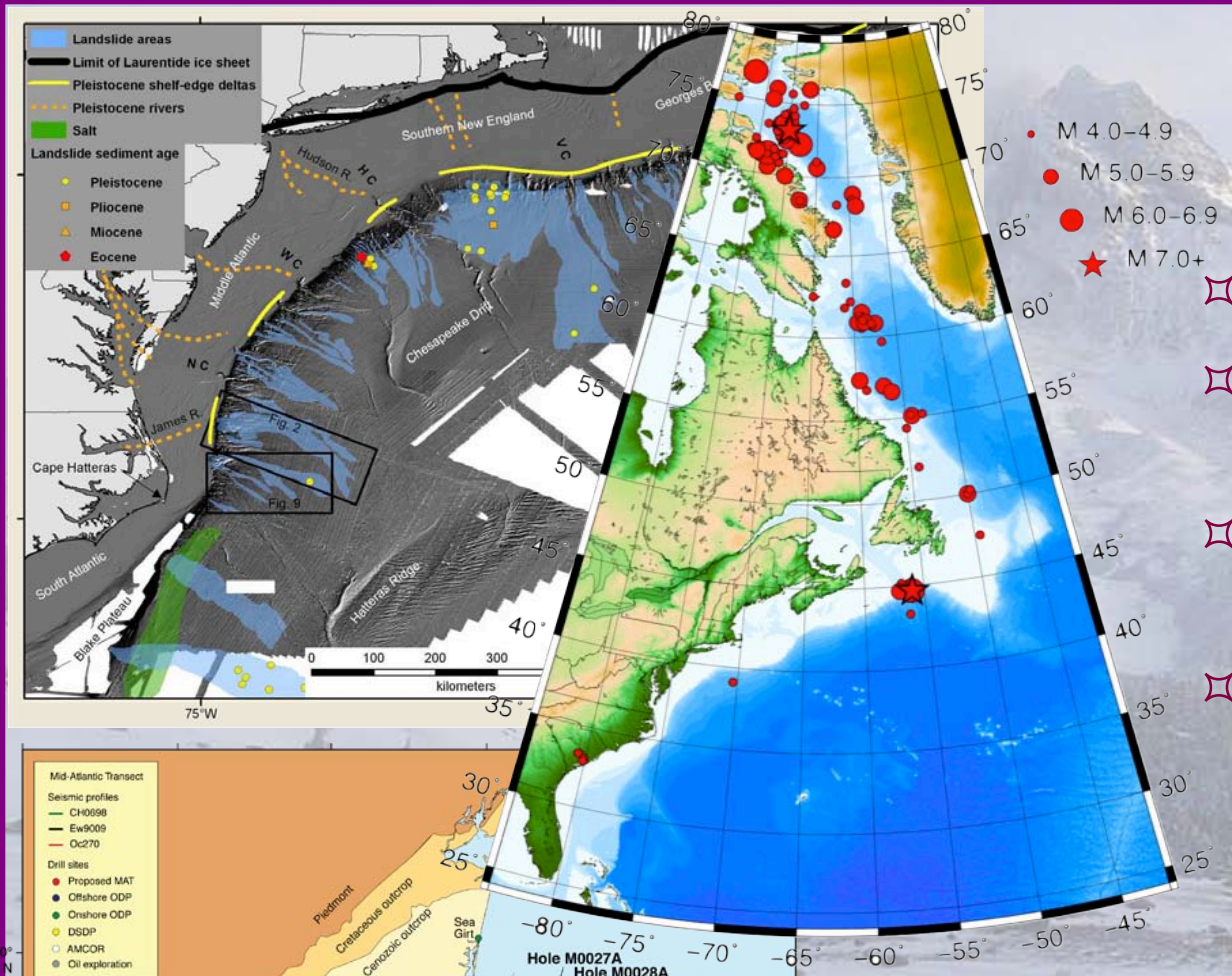
Map of Early Jurassic diabase dikes in eastern North America. Dikes in the north trend NE-SW, and were intruded during syn-rift extension. Dikes in the south trend NW-SE and N-S, cut across many rift basins, and likely post-date syn-rift extension. Modified from Withjack & Schlische (2005) based on McHone (2000) and McHone et al. (2004).

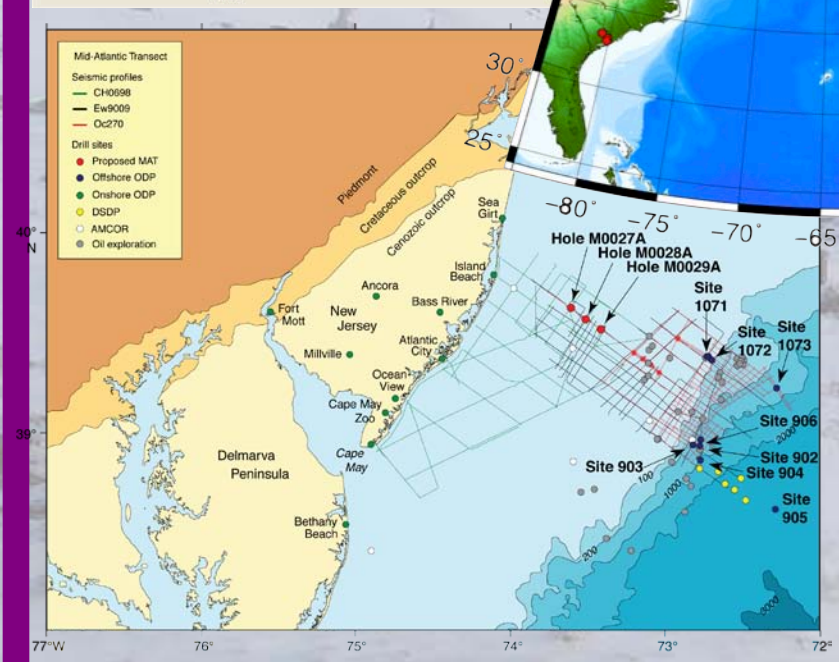
Map of the distribution of CAMP intrusive and extrusive rocks in North America, South America, Africa, Iberia and Europe plotted on a Pangea reconstruction. Abbreviations are: A=Argana basin; BP=Blake Plateau; C=Culpeper basin; CHA=Central High Atlas; D=Deerfield basin; F=Fundy basin; H=Hartford basin; N=Newark basin. Modified from McHone (2000) and Whiteside et al. (2007).

- Tectonic and magmatic inheritance in rifting
- Magmatism in rifting, breakup, and post-rift lithospheric evolution
- Relationships between breakup, rift-related magmatism, and CAMP
- Magma-rich to magma-poor transition
- Segmentation from initial rifting to mature seafloor spreading

- **Workshop – Oct 2011**
- **Implem. Plan released**

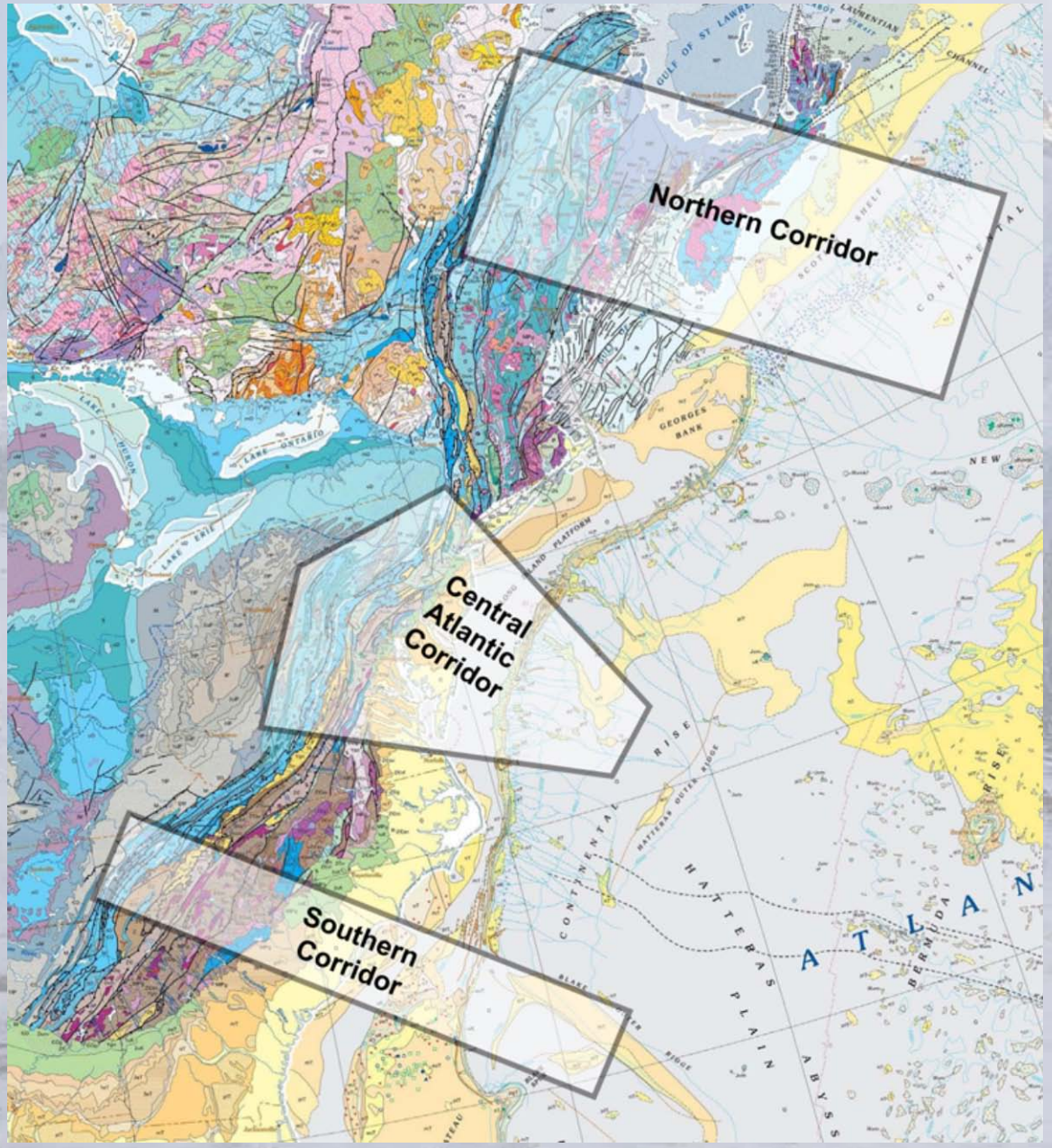
ENAM Primary Site





- Mass & elemental fluxes
- Controls on offshore landslides, distribution
- Rift structures & seismic hazard within ENAM
- Post-rift evolution: subsidence, epeirogeny, dynamic topography, landscape evolution, erosion, deposition
- Passive margin sed record: exposed & buried sequences

- **Workshop – Oct 2011**
- **Implem. Plan released**



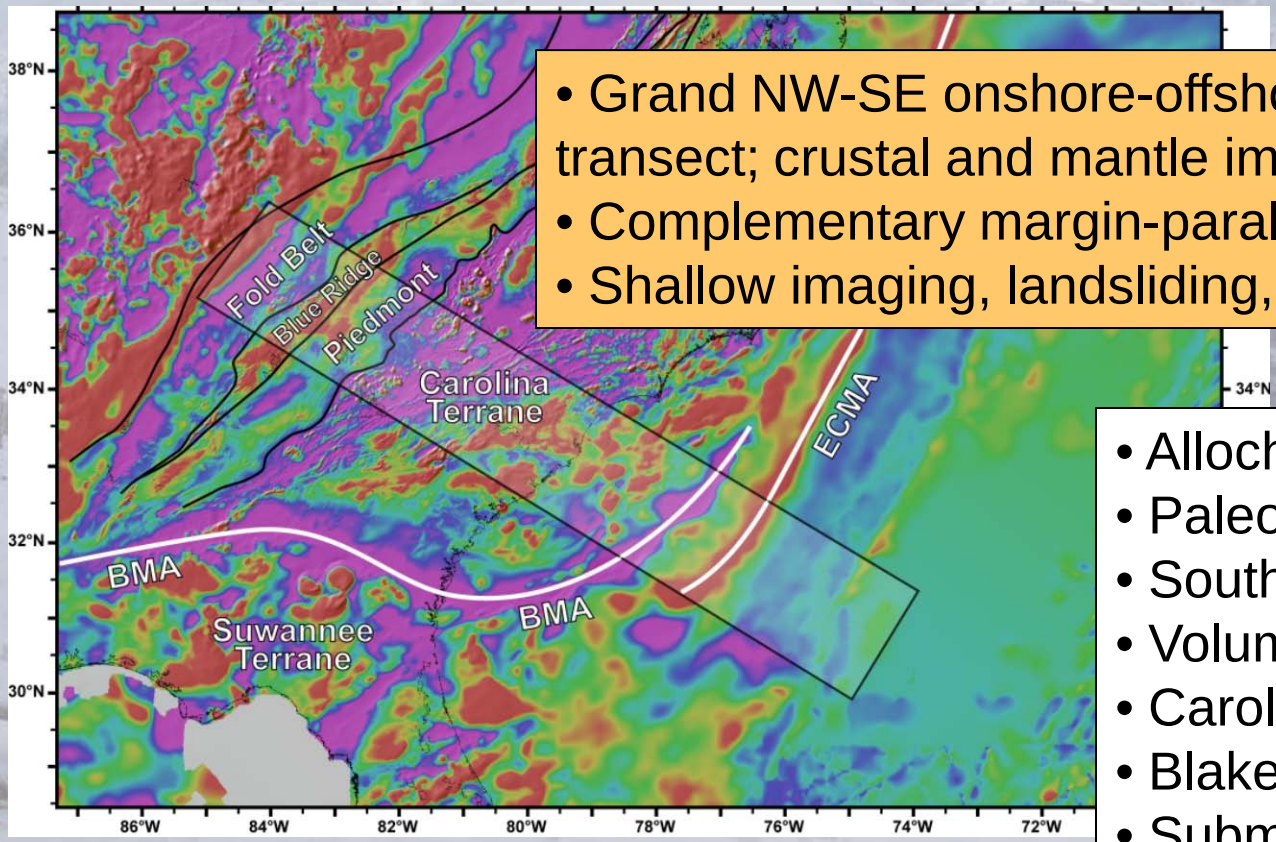
Discovery Corridors

- Focus Resources
- Leverage existing data concentrations
- Target key structures and transitions

- Southern (Charleston)
- Central (Richmond/Philly)
- Northern (Nova Scotia)

Southern Corridor *Charleston*

- ***The role of tectonic and magmatic inheritance in rifting and rift evolution***
- ***Role of magmatism in rifting, breakup, and post-rift lithospheric evolution***
- ***The relationships between breakup, rift-related magmatism, and CAMP***
- ***Relationships between rift structures and seismic hazard within ENAM***

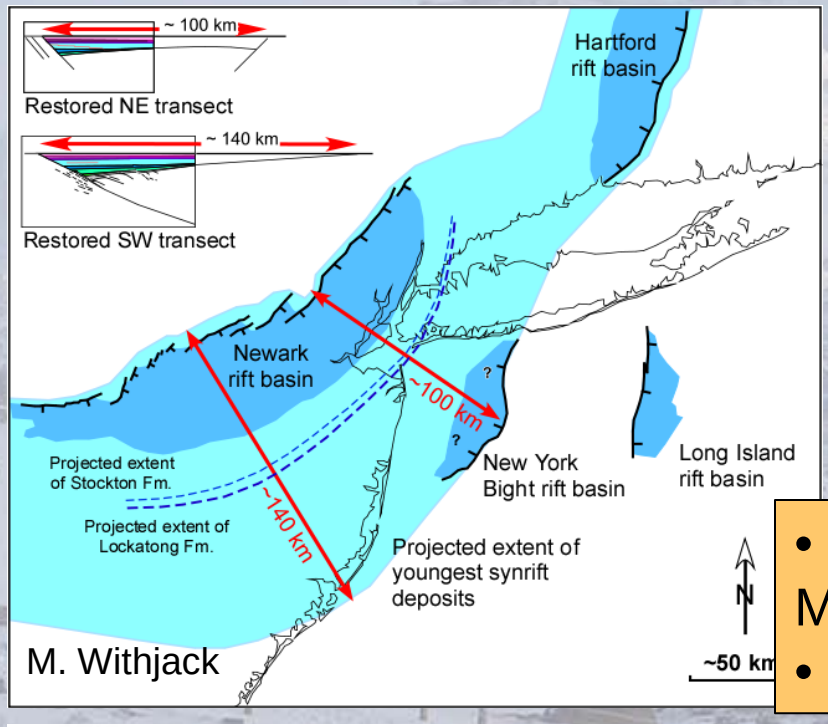


- Grand NW-SE onshore-offshore geophysical transect; crustal and mantle imaging
- Complementary margin-parallel profiles
- Shallow imaging, landsliding, surface processes

- Allochthonous terranes
- Paleozoic sutures
- South Georgia Basin
- Voluminous magmatism
- Carolina Trough
- Blake Ridge hydrate prov
- Submarine landslides
- Active seismic zones

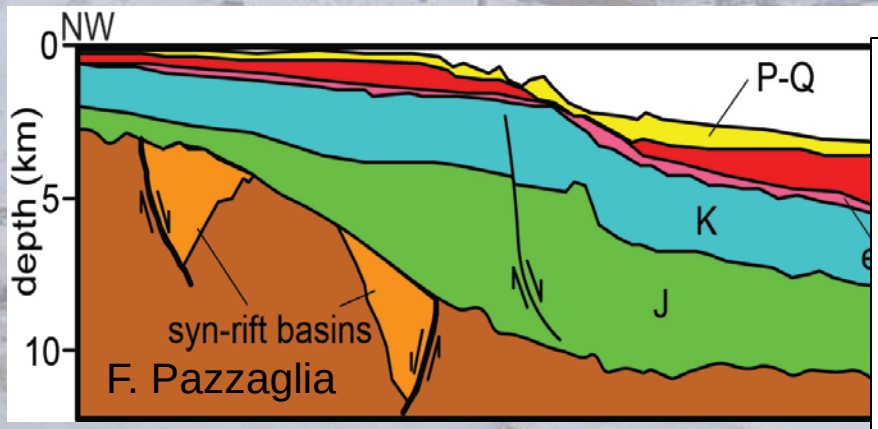
Central Corridor

Philadelphia and Richmond



- ***The role of tectonic and magmatic inheritance in rifting and rift evolution***
- ***The relationships between breakup, rift-related magmatism, and CAMP***
- ***Post-rift margin evolution, drivers and responses: subsidence, epeirogeny, dynamic topography, landscape evolution, erosion, deposition***

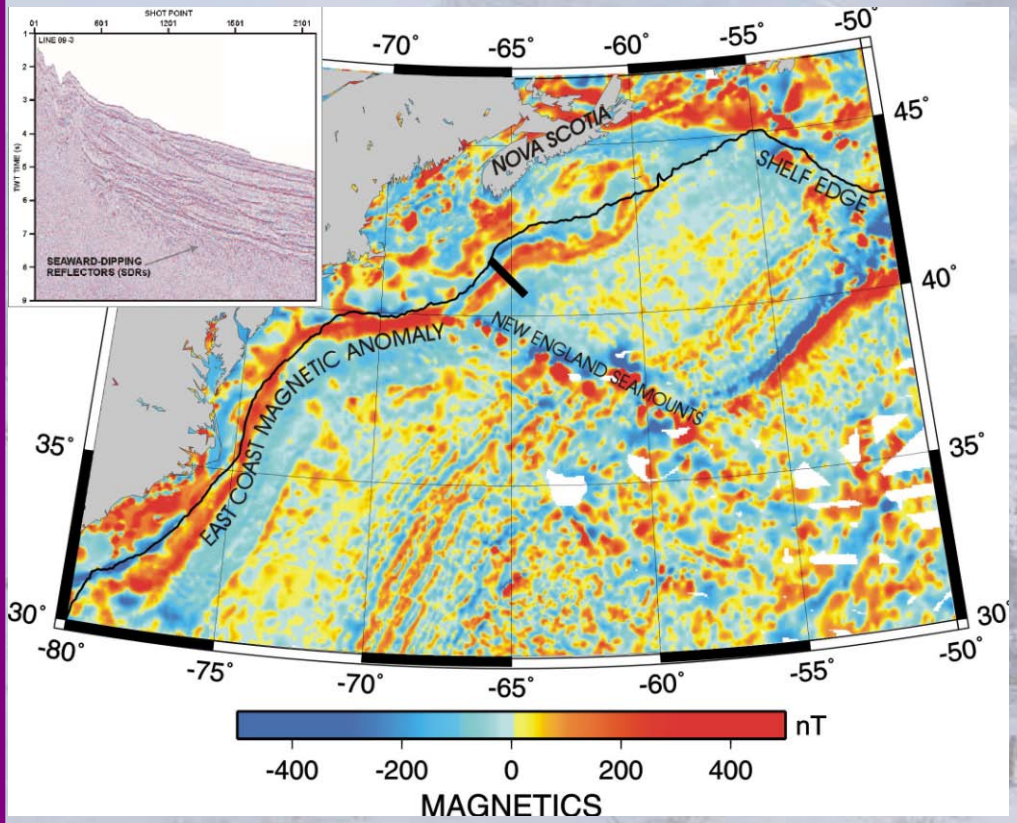
• Offshore active-source deep penetration MCS & OBS > velocity control (2D)
• 3D MCS to resolve sediment wedge



• Post-rift contraction and Mesozoic rift basin inversion
• Along strike changes in Appalachian structure, rift basins, and magmatism
• Active seismicity
• Well-imaged submarine sed wedge

Northern Corridor

Nova Scotia

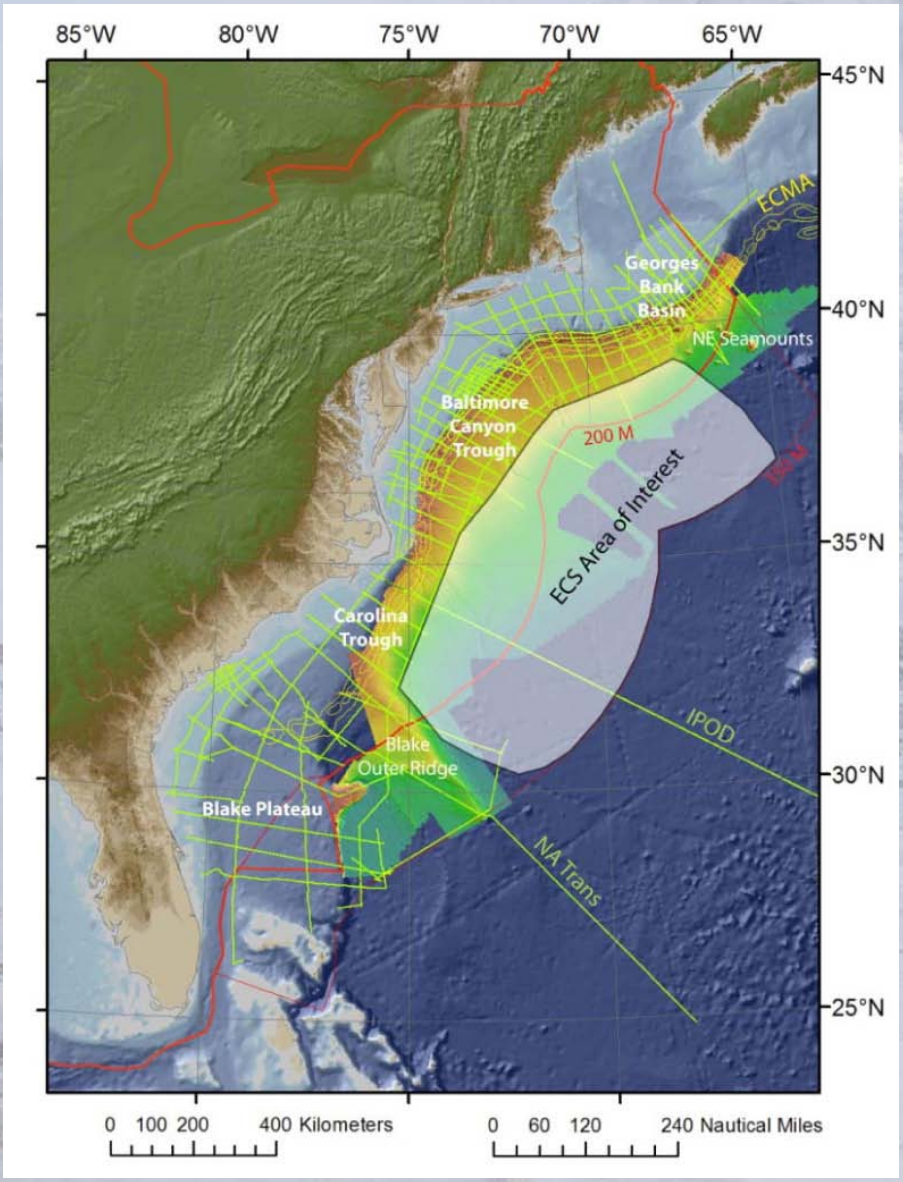


- ***The role of magmatism in rifting, breakup, and post-rift lithospheric***
- ***The along-strike transition from magma-rich to magma-poor extension at breakup***
- ***The evolution of segmentation from initial rifting to mature seafloor spreading***

- Transition from magmatic to amagmatic break-up
- Well-developed rift basins, post-rift inversion
- Industry quality seismic data

- Synthesis of existing seismic data over basins
- New MCS and OBS survey of ECMA transition
- Onshore-offshore passive seismic (and perhaps active source)

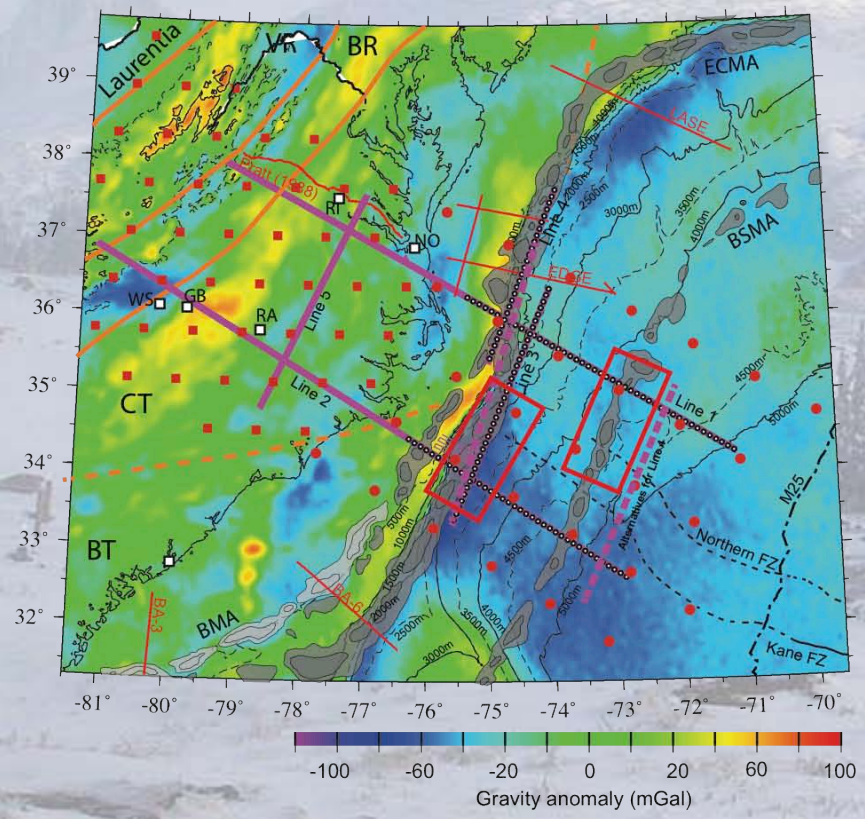
ENAM Community Seismic Experiment



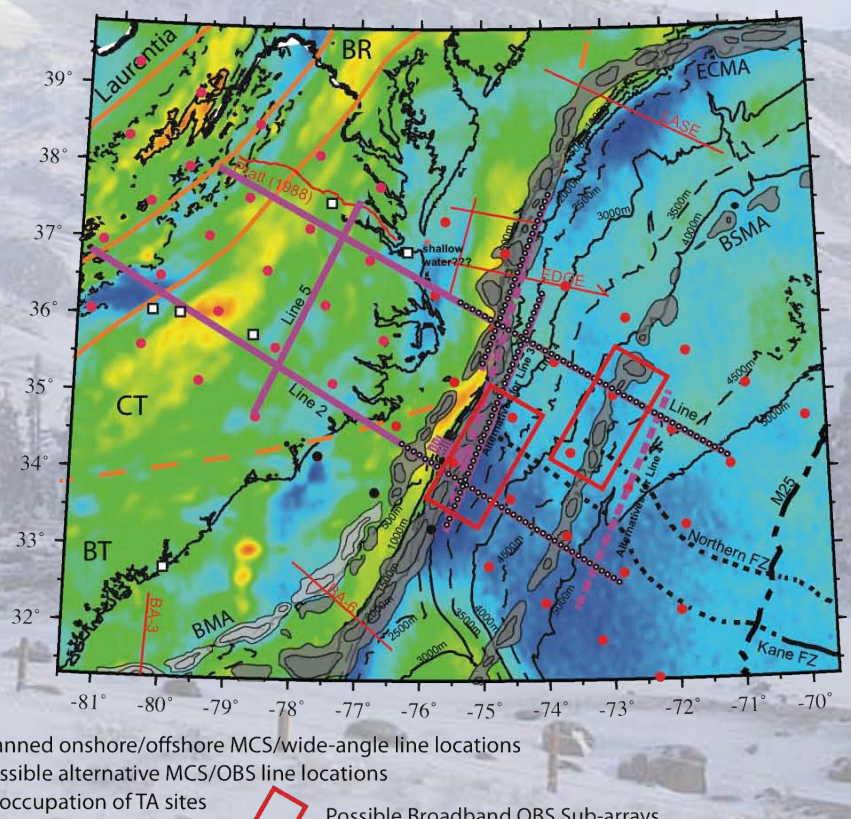
- Extended Continental Shelf 2D MCS survey, Law of the Sea - proposed by USGS on board Langseth (2013 or 2014)
- Opportunity for GeoPRISMS to piggy-back onto proposed project:
  - Extend some MCS lines toward shore
  - Wide-angle active source
  - Onshore passive & active with EarthScope support
- Open data access
- Possibility of expanded coverage with industry support

ENAM Community Seismic Experiment

Keep or Reoccupy TA onshore + OBS backbone array



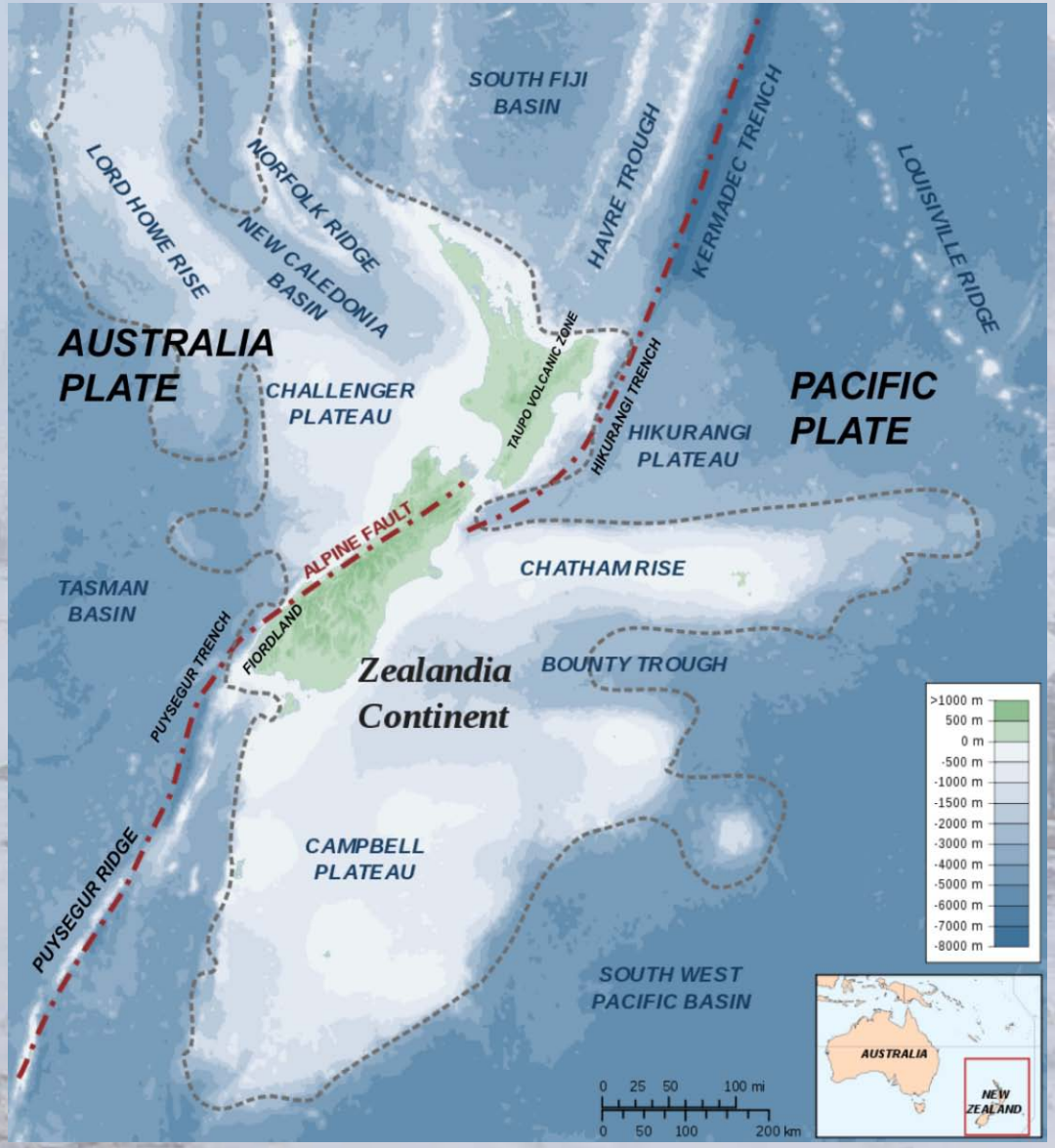
In-line Onshore + OBS backbone array



Planned onshore/offshore MCS/wide-angle line locations
Possible alternative MCS/OBS line locations
Reoccupation of TA sites
Broadband OBS
Short-period OBS
Possible Broadband OBS Sub-arrays of ~ 10 stations each

Proposal(s) to be submitted to NSF July 2012

New Zealand Primary Site



- Puysegur Ridge (subduction initiation)
- Puysegur Trench (subduction)
- Fiordland (exhumed arc crust)
- Hikurangi Trench (subduction)
- Taupo Volcanic Zone (arc and rift volcanism)
- Southern Kermadec Arc (subduction)
- Havre Trough (back-arc rifting)

To be prioritized – NZ Workshop, April 2013

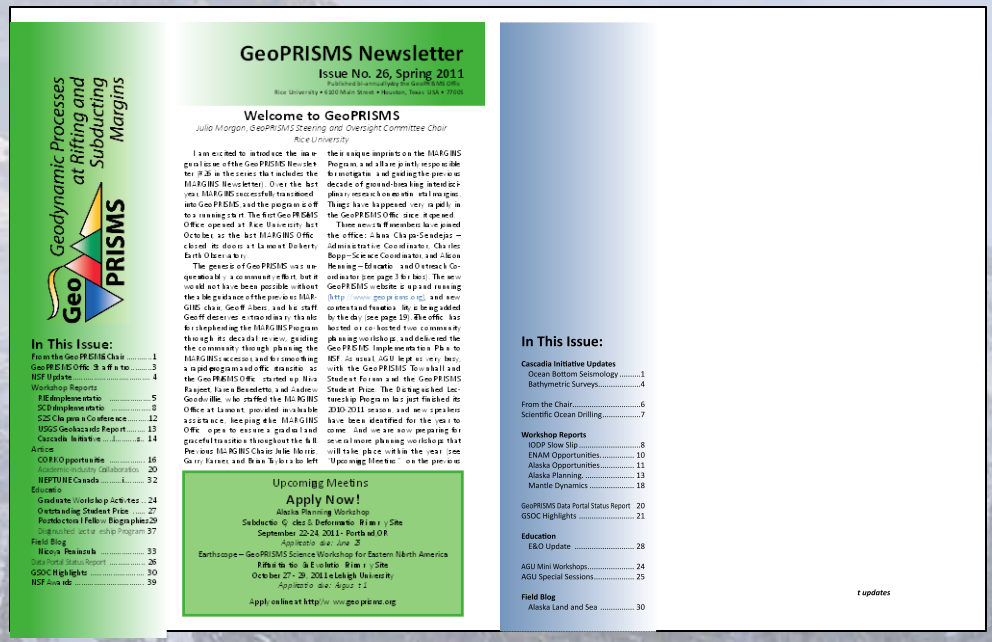
Example Topics

- Geological, geochemical and geophysical responses to subduction initiation and early arc evolution
- Along-strike transition from a locked subduction interface (southern Hikurangi) to a largely creeping interface (northern Hikurangi)
- Role of eustasy, deformation, and climate change on sediment dispersal and sequence architecture in forearc basins
- Magma transport pathways through the crust, and respective contributions of subducted sediments and crustal assimilation along- and across-strike of the arc
- Relationships of rifting and spreading, and the spatial and temporal variation of magmatism, to the nature of slab-derived fluid-to-melt and the rheology of the mantle wedge?

- 2D (and 3D) MCS surveys of slow slip patches for IODP site survey
- Sediment dispersal and stratigraphic architecture

Communications & Data Access

- **Communication**
  - GeoPRISMS website
  - GeoPRISMS newsletter
  - GeoPRISMS listserv
- **Data Access**
  - GeoPRISMS Data Portal
  - MARGINS Data Portal



More info: ***http://www.geoprisms.org***

GeoPRISMS Thematic Studies

Themes

- Subsidiary but complementary to primary site studies,
  - Fundamental processes, parameters not at primary sites
  - Comparative studies; exhumed systems; lab, modeling studies
- Justified in the context of, and integrated with, primary site (and MARGINS focus site) studies

SCD

- *Identifying controls on fault slip behavior and deformation history*
- *Understanding mantle wedge dynamics*
- *Fore-arc to back-arc volatile fluxes*
- ***Metamorphic & igneous conditions and processes in subduction zones at depth***
- *Subduction initiation*

RIE

- *Rift obliquity*
- *Rift processes as functions of strain rate*
- *Volatiles in rift zone processes*
- *Sediment production, routing and transport during and after rifting*
- *Discrete events at rifted margins*