Overview and Future Perspectives on Subduction Zone Processes

Katherine A. Kelley
University of Rhode Island
Subduction Factory

3.3 S2S Initiative Summary

3.4 Initiative Summary:

- Source
  - Weathering
  - Hillslope erosion
  - Landslides
  - Glacial erosion
  - Glacial runoff
  - Streams
- Sink
  - River transport
  - FLOOD plains
  - Shoreline
  - Stratigraphy
  - Shelf circulation
  - Reefs
  - Banks
  - Submarine canyons
  - JFIs
  - Fords
  - Contour currents

Modified from JP Walsh

- Oceanic crust
- Sediment stratigraphy
- Ridge crest
- Continent-ocean

Lower Mantle
Upper Mantle
Crust

Serpentine and fluid forearc output
Volcanic arc output
Rear arc volcanism

Input flux

Subduction plate interior

Fluids

Magmas

Mantle flow

Back arc spreading

Drill to seaward limit of seismogenic zone

Image seismogenic zone using earthquakes and artificial sources (seismic reflection/refraction)

Seafloor observations and monitoring

Predict nature of materials in seismogenic zone

Seismogenic Zone

Measure surface deformation

Characterize incoming materials
SubFac: Big 3 Themes, 2 Focus Sites

1. Forcing functions
2. Volatile cycling
3. Crustal growth
SubFac: Big 3 Themes, 2 Focus Sites

1. Forcing functions
2. Volatile cycling
3. Crustal growth

Izu-Bonin-Mariana
Central America
Looking Ahead: Ideas for New Thematic Arenas

Decadal Review (SubFac)
Volatiles TEI (Sept. 2009)
MSPW White Papers
Looking Ahead: Ideas for New Thematic Arenas

Decadal Review (SubFac)
Volatile TEI (Sept. 2009)
MSPW White Papers

• Media, pathways, and magnitudes of volatile/mass transport and exchange

• Physical/chemical conditions of transformative reactions

• Un-/under-explored spatial and temporal scales of subduction processes

Discuss some examples (not an exhaustive list!)
Media, pathways, and magnitudes of volatile/mass transport and exchange
Media, pathways, and magnitudes of volatile/mass transport and exchange

What are the key volatile-rich minerals and input budgets to subduction zones?

E.g., importance of serpentine, how heterogeneous are slabs?

Ranero et al., 2003
What volatile-rich phases are present in the mantle wedge, and what role do they play in controlling element budgets, fueling melting, etc.?

E.g., chlorite breakdown in the wedge coincides with wet solidus
What are the pathways and mechanisms by which fluids and melts migrate through the slab and mantle wedge?

E.g., relationships between solid flow regime vs. fluid/melt migration vectors
Physical/chemical conditions of transformative reactions
Physical/chemical conditions of transformative reactions

What is the fate of volatiles in the slab and wedge in the critical slab dehydration zone (bottom of seismogenic zone to sediment melting; 200-750°C)?

SubFac and SEIZE crossover; E.g., what is the full progression of slab devolatilization?

[More on the critical interface zone from Kelin Wang]
Physical/chemical conditions of transformative reactions

What are the P-T-X-fO₂ conditions of important reactions, and how do these relate to geophysical and geochemical observables?

- slab dehydration
- mantle wedge melting
- magmatic differentiation/degassing/storage

E.g., melt thermobarometry combined w/ seismic imaging can relate “red” to melt-rich regions

Kelley et al., submitted
Q model from Pozgay et al., 2009

Red: 1000/Qₚ=12
Physical/chemical conditions of transformative reactions

How do primary subduction zone magmas transform into continental crust?

Tatsumi et al., 2008

E.g., What processes are needed to change “normal” arc basalt into intermediate continental crust? Or are “special” parent magmas required?
Un-/under-explored spatial and temporal scales of subduction processes
Un-/under-explored spatial and temporal scales of subduction processes

What are the spatial scales of variability in slab, wedge, and arc crustal structure, and how are individual volcanoes linked to processes at depth in the arc crust, mantle wedge and slab?

Arc middle crust varies in thickness, correlates with volcano composition
Un-/under-explored spatial and temporal scales of subduction processes

What are the spatial scales of variability in slab, wedge, and arc crustal structure, and how are individual volcanoes linked to processes at depth in the arc crust, mantle wedge and slab?

- UHP metamorphic rocks
- Exhumed mantle wedges (ophiolites)
- Focused volcano/pluton studies
Un-/under-explored spatial and temporal scales of subduction processes

How does 3D flow within the mantle wedge influence or interact with melt, the subducting slab, or the arc lithosphere?

E.g., most dynamic models are 2D, we are accustomed to looking mostly in cross-section.

King et al., White Paper
Un-/under-explored spatial and temporal scales of subduction processes

At what rates do slab dehydration, mantle melting, magma emplacement, and crustal growth happen, and what factors control these rates?

Reymer & Schubert, 1984

E.g., how fast is magma produced, and how fast does arc crust grow?
Un-/under-explored spatial and temporal scales of subduction processes

How does subduction begin, end, and evolve through time?

E.g., magmas made at the beginning of subduction differ from “mature” arc magmas

Gurnis et al., White Paper
Summary

• Wealth of ideas/directions, some ideas here on ways to organize and group themes

∞ Media, pathways, and magnitudes [transport and exchange]

∞ Transformative reactions

∞ New dimensions of subduction processes [space and time]

Up Next: Kelin Wang, interface zone between slab and overriding plate/mantle wedge