ExTerra: Exploring Subduction through the Study of Exhumed Terranes
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Overview Studies of rocks exhumed from fossil subduction zones (**Ex**humed **Terra**nes) contribute greatly to our understanding of the materials and processes hidden beneath the surface in active subduction zones. Rather than focusing on a particular active margin, we target three areas interior to (and thus invisible in) active subduction zones that may be subsequently exposed in exhumed terranes: middle and lower arc crust, the subducted slab, and the mantle wedge. Key scientific questions are identified for each target area. Interdisciplinary field institutes are proposed as a primary venue for collective research on exhumed terranes. Scientists and students will travel together to exhumed fossil subduction zones to map, discuss, and collect samples. The institutes will generate collaborative research, with published results that will enhance understanding of active subduction zone processes within the SZO community. Together, researchers will explore specific science questions identified by this white paper. Sample and data management are an integral part of the ExTerra effort, and will be conducted in cooperation with IEDA, making use of existing and evolving data repositories and sample management systems including SESAR and MetPetDB. Further details of the ExTerra model for research and education in fossil subduction zones can be found in Feineman et al., 2013 (ExTerra White Paper).

Science Questions Below are examples of scientific questions to be addressed using samples collected from each of the three identified target areas of fossil subduction zones. Collaborative research around a common sample set will further allow us to address those questions that tie the three target areas together; namely, the mechanisms, pathways, and timescales by which material is transferred from the slab to the mantle wedge and onward into in the arc crust.

Arc Crust - Exhumed rocks include granitoids, gabbros, metasedimentary rocks (commonly migmatized), gneisses, amphibolites, pyroxenites (with or without garnet), and granulites.

- *What are the geochemical products of subduction that influence formation and evolution of continental crust?*
- *What are the fluxes into and out of arc crust over time? How and where is magma transported and stored in the crust?*
- *What is the extent of exchange between arc magmas and arc crust? How do cumulates, restites, and wall rocks influence magma evolution?How variable is the bulk composition, fabric, melt/fluid content, and thermal structure of arc crust? How might these influence our interpretation of seismic velocity profiles?*
- *To what extent are the volcanic products of subduction zones representative of the hidden plutonic components in the crust? What percentage of arc magma is erupted at the surface, relative to what is retained in plutons?*
- *What is the mode of emplacement of metasedimentary rocks in arc lower crust (~1 GPa)? Gradual burial, lateral thrusting, diapirism from below?*
- *What is the bulk composition of continental arc crust? What is the bulk composition of oceanic arc crust? How and why do they differ?*

Subducted Slab - Exhumed rocks include high-pressure (HP) and ultrahigh-pressure (UHP) rocks such as blueschists, eclogites, and metasedimentary rocks.

- *What are the compositions, pathways, fluxes, and timescales of materials released from the slab (e.g., fluids, melts, mélange)?*
- *What is the thermal and mechanical evolution of the slab?*
- *What are the reaction and diffusion rates at conditions relevant to subducting slabs? To what extent do metamorphic reactions "keep up" with changing pressure-temperature conditions in the slab?*
- *What can the rock record reveal about mechanical behavior associated with subduction-related seismic events?*

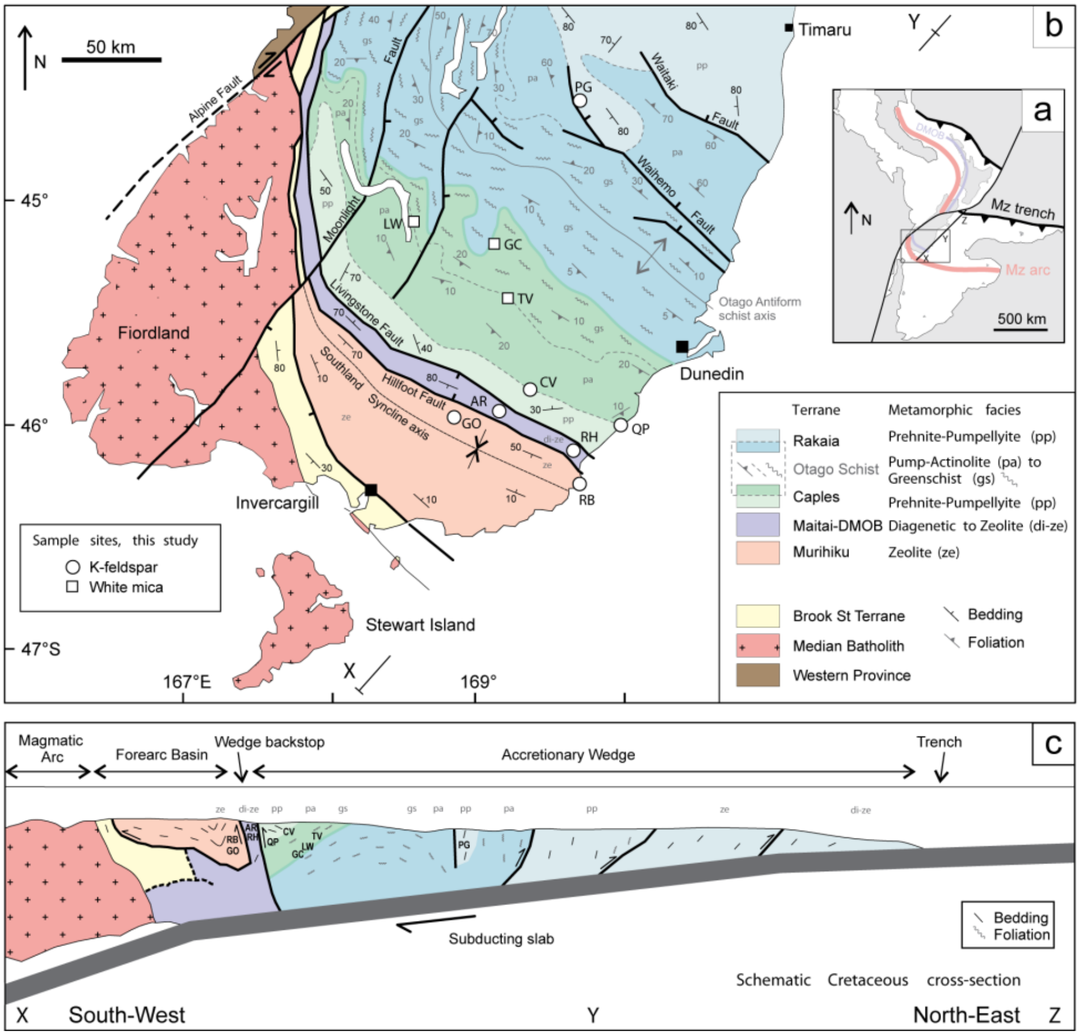
Mantle Wedge - Exhumed rocks include serpentinites, peridotites, and variants thereof (dunites, lherzolites, pyroxenites, etc.).

- *How does the addition of fluid or melt from the slab affect the composition and rheology of the mantle wedge?*
- *What is the mass fraction contributed by the mantle wedge during the generation of arc basalts?*
- *How does the mantle wedge evolve temporally in response to fluid addition and melt extraction?*
- *What are melt extraction rates and fluid fluxes through the wedge? Are fluxes uniform, in pulses, channelized, in diapirs?*
- *How prevalent is serpentinization, and what are the properties of serpentinite (i.e., antigorite) at the slab/mantle interface?*
- *What is the mass balance of carbon through the subduction system? How much carbon is sequestered in the mantle wedge via carbonation and serpentinization, and what is the ultimate fate of this subducted carbon?*

Field Institutes Focused, interdisciplinary field institutes bring together researchers from diverse backgrounds and initiate an interdisciplinary thought process with respect to visualizing the subsurface at subduction zones. Under a joint research and educational mission, scientists and students will travel together to map, discuss, and collect samples that will contribute to the community effort towards understanding active subduction zone processes. Field institutes will explore specific science questions for a given portion of the subduction zone as identified above. Student participation in field institutes will be facilitated by on-site pre-fieldtrip symposia, during which students will receive additional background information regarding subduction zone anatomy and dynamics, exhumed terranes, and the motivation behind the specific scientific questions to be explored during the field institute. Field workshops will include a culminating 1-2 day meeting for reflection in a small local conference venue, providing participants valuable time to summarize group observations, identify key tasks, and establish clear goals to carry meaningful research onwards towards a productive (i.e. published) outcome. Each of the proposed **Subduction Zone Observatory** focus sites is associated with one or more exhumed terranes suitable for fossil subduction zone exploration. Selected examples are given here.

- **Mexico, Central and South America**
  - Baja (Sedlock 1988, Baldwin and Harrison 1989, Sorenson et al 1996), Valle Fertil (Otamendi et al. 2009, 2012; Ducea et al. 2010)
- **Cascadia and Alaska**
  - Josephine Peridotite (Dick 1977, Kelemen and Dick 1995), North Cascades / Skagit Gneiss (Evans and Berti 1986, Whitney 1992, Miller et al. 2009), Talkeetna (DeBari and Sleep 1991, Greene et al. 2006, Behn and Kelemen 2006, Hacker et al. 2008, Rioux et al. 2010), Coast Mountains Batholith (Brown and Walker 1993, Gehrels et al. 2009, Girardi et al. 2012)
- **Indonesia and SE Asia**
  - Papua New Guinea (Baldwin et al. 2004, Brownlee et al. 2011, Little et al. 2011, Gordon et al. 2012)
- **Japan and New Zealand**
  - Sanbagawa (Ernst and Seki 1967, Banno and Sakai, 1986, 1989, Nakano and Nakamura 2001), Fiordland (Klepeis et al. 2004, Stowell et al. 2010a,b, Mortimer et al., 2012).

Integration of research and education through field institutes at exhumed subduction terranes near margins where study of active subduction is targeted for study will contribute greatly to a subduction zone observatory. Sample and data sharing under the model developed by ExTerra (see http://geoprisms.org/exterra/field-institutes/exterra-2014-salinia/day-1-stop-1/) will provide research and education opportunities beyond the duration of the field institutes themselves and engage a broader community in the SZO mission.



Top: One example of an exhumed arc crust section: The Fiordland, South Island, New Zealand. Geologic map and schematic Cretaceous cross-section shown. Mortimer et al, 2012.
Bottom Left: Student-faculty interaction during the ExTerra Salinia Field Institute in 2014, near the fault contact between the Salinian arc crust block and the Franciscan oceanic slab exposure.
Bottom Right: Contact between upper mafic complex and metasediments forming stomatic migmatites with leucogranite, and back-veining into gabbro from the Sierra Valle Fértil. Photo credit: George Bergantz.

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