Exterra: Understanding Convergent Margin Processes Through Studies of Exhumed Terranes – GeoPRISMS New Zealand Focus Site

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The GeoPRISMS SCD Science Plan identified the study of exhumed terranes as an important component of subduction zone research. Exhumed rocks from the accretionary wedge, forearc, subducted slab and middle to lower arc crust can illuminate the role of volatiles, fluids and melts, and geochemical cycling during subduction, leading to a better understanding of continental crust formation and evolution. Also, analysis of exhumed terranes has the unique ability to inform studies of active subduction by testing the assumptions required by models, experiments, and interpretive geophysics and geochemistry.

New Zealand Focus Sites

***1) Otago Schist (OS),* Fig. 1a:** Investigation of exposed accretionary wedge rocks, such as the *OS*, allows the disentanglement of mixing and material transport processes occurring within and above the subducting slab. The *OS* is a >150 km wide belt of deformed and metamorphosed greywacke, basalt, shale, and chert [1-4]. This unit is considered to represent the exhumed section of a Late Paleozoic-Mesozoic accretionary prism, formed by subduction under the Paleo-Pacific Gondwana margin [5-8]. Peak temperatures of the central greenschist facies unit are estimated to have reached 350-400°C [1, 3]. The *OS* displays extensive vein formation and associated metasomatism, exhibiting evidence for subduction-related reactive fluid flow [6, 9].

***2) Fiordland Block (FB),* Fig. 1b:** A major limitation in understanding the magmatic evolution of continental margin-arc systems is our limited knowledge of magmatic, metamorphic and deformational processes that occur in the deep crust. Well-exposed middle and lower arc crustal terranes (e.g. the *FB*), can provide key spatial and temporal constraints on the evolution of arc magmas that *cannot be addressed directly through studies of erupted lavas*. This helps us to construct a 4-D geologic perspective of a continental margin-arc system that relates field-based petrologic observations to those derived from deep-crustal seismic reflection imaging and laboratory-based partial melting experiments. The *FB* exposes >3,000 km^2 of Mesozoic middle and lower crust that records a history of mafic-intermediate arc magmatism, lower crustal melting, and high-grade metamorphism [10, 11]. Eclogite, granulite, and amphibolite facies rocks of the *FB* constrain metamorphic depth and temperature [12-15]. Garnet Sm-Nd and zircon U-Pb ages indicate that high temperature metamorphism closely followed magmatism in parts of Fiordland [14, 16-17] providing an opportunity to test ties between arc magmatism, high temperature metamorphism, exhumation, and partial melting in the crust.

Key questions addressed by the study of exhumed terranes *(and relevant proposed study site)*

*What is the composition of slab-derived fluids? How do processes in the forearc and accretionary wedge affect the overall subduction zone elemental budget? (**OS**)* Knowledge of the composition of slab-derived fluids is largely derived indirectly from elemental variations in arc lavas [18, 19], experiments [20, 21], or theoretical calculations [22]. The *OS* offers field evidence for extensive fluid flow and elemental mobility [6, 9, 23, 24]. Fluid flow in accretionary prisms is driven mainly by expulsion of pore waters from sediments, devolatilization from (meta)sedimentary rocks, and dehydration of the subducting slab and/or forearc mantle wedge. Mineral scale data from these locales are needed to test and ground-truth existing experiments that constrain the solubility of minerals and elemental partitioning between minerals and fluids, placing these within the context of a dynamic subduction environment.

*What are the pathways, fluxes, and timescales of fluid release in the slab? What is its thermal evolution? (**OS**)* Models of fluid production based on thermodynamic equilibrium [25, 26] can predict volumes of fluid released during subduction. Patterns of fluid release during *OS* evolution can be quantified using thermo-petrologic models [27,28]. Geospeedometry suggests rapid timescales of fluid release on the order of hundreds of years [29, 30], while geochronology has the potential to constrain timescales and fluxes [28] on the order of hundreds of thousands of years. The *OS* provides insight into the mechanisms of fluid transport, paths, and fluxes in the accretionary wedge [6, 9]. Geochronology combined with thermodynamic modeling can yield petrologically-derived *P-T-t* paths, providing constraints for geodynamical models of subduction zones.

*What are the geochemical products of subduction that influence the formation and evolution of continental crust? (**FB**)* The FB contains Mesozoic tonalite-trondjhemite-granodiorite (TTG)-like plutons [11, 31]. Modern analogs of TTGs are believed to form by partial melting of underplated basaltic materials at the base of the arc crust [32] (and/or high pressure garnet fractionation). This demonstrates that contributions to the long-term growth and evolution of continental crust come not only from mantle-derived melts that erupt at continental arcs, but also from more evolved plutons that form within the deep crust. The *FB* provides the opportunity to investigate the structure and chemistry of these plutons directly in a relatively intact crustal sequence.

*What are the fluxes into and out of the crust over time? (**FB**)* Mantle and slab-derived melts (and possible sediment relamination onto the base of the arc) provide fluxes into the crust, while delamination and erosion represent mass loss from the crust [33, 34]. Petrologic and geochronologic evidence for rapid heating and exhumation may provide supporting evidence for delamination and links to possible vertical movement [35]. Interdisciplinary studies of the *FB* will address the relationships between crustal melt generation and metamorphism, including: i) *Is magmatism steady state or punctuated?* ii) *How do timescales of arc magmatism and thermal perturbations associated with magmatic advection relate to granulite-facies metamorphism and lower crustal cooling?* iii) *What role does high-pressure mineral fractionation play in the intracrustal differentiation of arc magmas and the possible foundering of ultramafic cumulates?*

How variable is the composition, fabric, melt/fluid content, and thermal structure of the arc crust, and how might these properties affect seismic velocity profiles? (***FB***) Models for lateral and vertical crustal flow (that have previously been developed for collisional orogenic belts) [36, 37] can be tested in the *FB*, providing an opportunity to study how flow and ductile deformation affect the rheological evolution of an arc. Interpretation of seismic velocity data requires knowledge of physical properties of the low velocity middle to lower arc crust. *FB* offers an opportunity to directly observe the stratified petrology that contributes to the horizontal complexity of the crust.

Data and sample management

An integrated database and sample archive will allow field geologists to connect with users requiring samples (including experimentalists, petrologists, geochemists, or researchers who cannot participate in fieldwork due to health, time, or cost limitations). Samples collected during targeted field expeditions and seminars will be archived, magnifying the scope and impact of the field mission by making samples available to the wider research and education community. PETLAB (http://pet.gns.cri.nz/) was developed by GNS Science to manage and archive samples and associated analytical data. It allows immediate dissemination of data that enables its timely use, and currently holds a diverse collection of records on 185,000 samples of which 50,000 have geochemical, geochronological and/or thermochronological analytical data. ExTerra will work with the US-based Integrated Earth Data Applications (IEDA) facility to develop an interface with PETLAB. PETLAB should be added to the GeoPRISMS Data Portal, and could then be systematically encouraged for use by all GeoPRISMS projects working on the NZ primary site.

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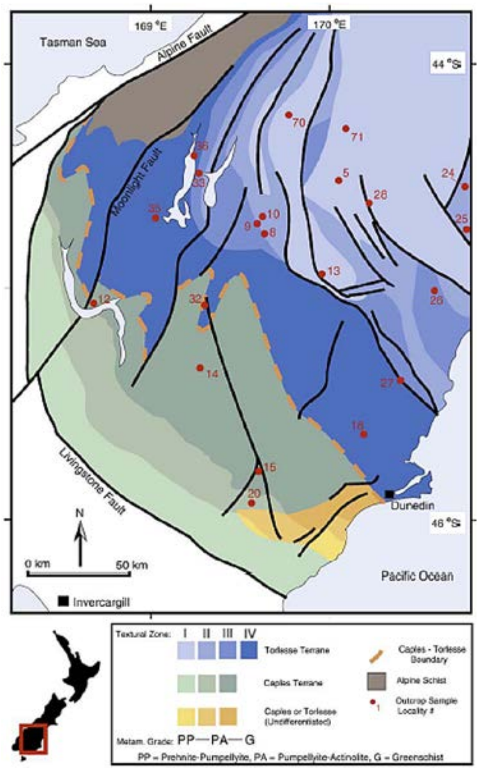

Figure 1A. Geologic map of the Otago Schist. [9].

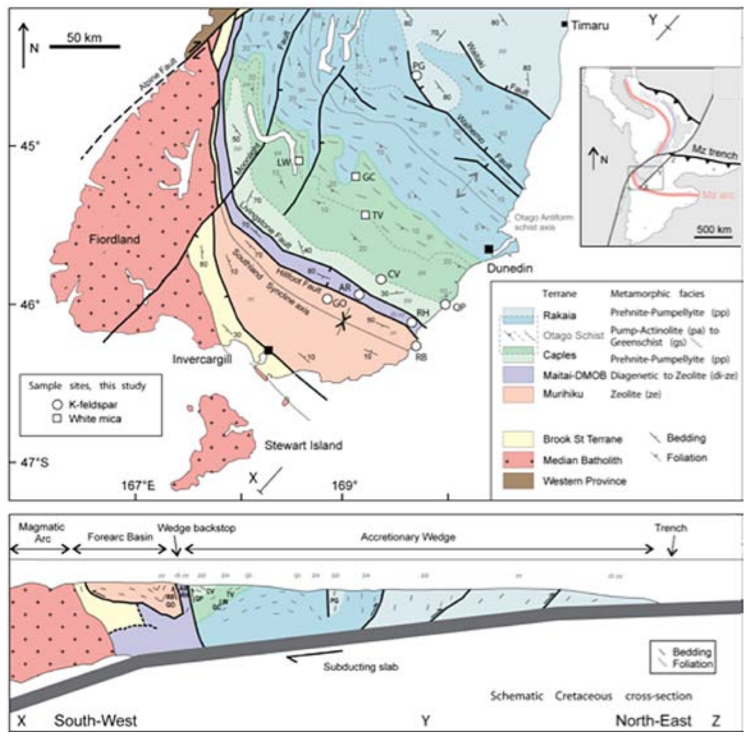

Figure 1B. Geol. map of the basement rock of NZ south. South Island. [3].