

# Masters/Bachelor Projects and assistant studentships (Hiwi)

within DFG-funded research\* **Orogenic and xenolithic eclogites as recorders of mass transfer in subduction zones: A unique case study from the Farallon plate**

**Summary:** Constraining the transfer of volatiles and other elements in subduction zones is uniquely important for understanding past and future Earth system evolution. Due to a unique geological happenstance, the oceanic crust of the Cretaceous Farallon plate has been sampled over an exceptionally large pressure interval (~2.0-4.7 GPa), by tectonically exhumed eclogites in the Franciscan Complex (western United States), and by eclogite xenoliths occurring in the Navajo Volcanic Field, 700 km to the east (Fig. 1a,b). Using a representative sample suite (Fig. 1c), this study aims to fingerprint the sources of the fluids that interacted with the eclogites during deep mass transfer processes in the Farallon plate. This will be achieved using bulk-rock stable isotope compositions, while short-lived fluid flow events will be detected with mineral stable isotopes. A pressure-temperature-time-oxygen fugacity path (Fig. 1d) will be delineated by combining geothermo-oxybarometry with a novel garnet U-Pb dating tool. Bulk and mineral S and Fe isotopes and oxidation state will be used to assess the interplay between the redox-sensitive elements Fe, C and S, and identify the reactions by which they are mobilised or retained in the slab. Using also state-of-the-art instrumentation at Goethe University Frankfurt (Fig. 1e), these data will allow to trace the physicochemical controls on mass transfer processes and volatiles in a single slab with unprecedented detail.

\*April 22-March 25

**This project offers students with interest in high-temperature processes and geochemistry the opportunity to participate in cutting-edge research using state-of-the-art instrumentation at Goethe University**

**Contact: Dr. Sonja Aulbach, s.aulbach@em.uni-Frankfurt.de, room 1.334**

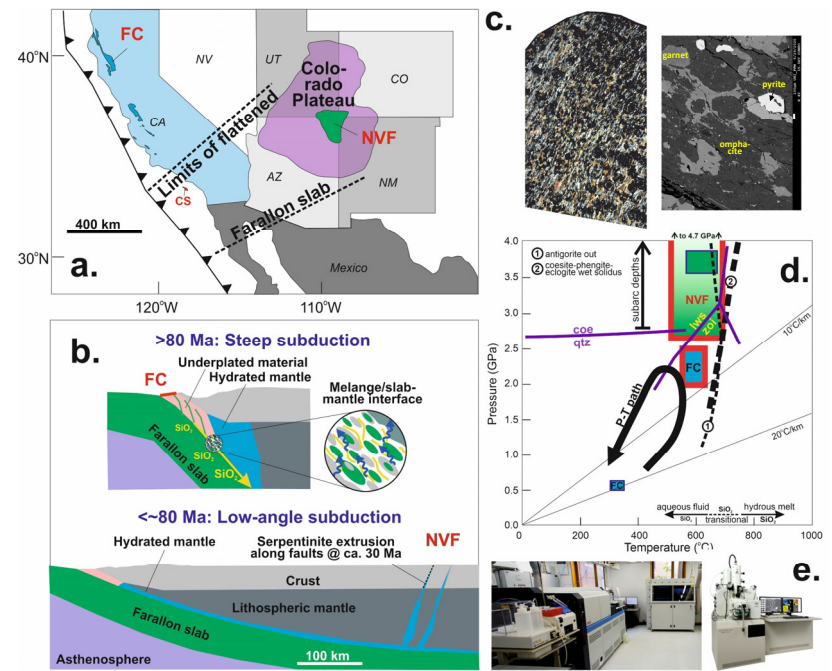


Fig. 1 a. Map of the southwestern USA with location of Franciscan Complex (FC) eclogites and outline of the Navajo Volcanic Field (NVF) and Colorado Plateau, as well as the trace of the Farallon plate after initiation of flat subduction. b. Cross-section sketch of Farallon plate, the underlying asthenosphere and overlying hanging wall with underplated material and hydrated mantle prior to (top) and after (bottom) onset of low-angle subduction. c. Standard thick section (2.8x4.8 cm) with cross-polarised light and e. backscatter electron image of a typical zoisite eclogite xenolith. d. Pressure-temperature estimates for peak metamorphic conditions and suggested pressure-temperature path for FC eclogites. f. The electron probe (right), and mass spectrometers with and without coupling to a laser system (left) are key instruments for geochemical analysis of samples in this study.

## MSc Project 1

### Reconstructing the Pressure-Temperature-Time Path of eclogite from the Farallon Plate

**Background:** Pressure and temperature, and their evolution as the oceanic crust enters a subduction zone and is tectonically exhumed back to the surface, control metamorphic and metasomatic reactions and the loss of fluids and melts.

**Aims and approach:** Establish pressure-temperature-time (P-T-t) paths (Fig. 1d) for the oceanic crust of the Farallon plate, by applying major-element garnet-phengite-clinopyroxene thermobarometry to appropriate assemblages, in combination with spatially resolved U-Pb dating techniques. This will permit locating the samples' position in the slab prior to exhumation.

**Analytical techniques:** Minerals in 10-15 representative samples will be analysed in situ for major and minor element composition using the electron probe microanalyser (Fig. 1e). Novel in-situ U-Pb dating of garnet will place absolute age constraints on prograde (e.g. garnet cores) and retrograde processes (e.g. rims). This will employ the ThermoFinnigan Element XR sector-field inductively-coupled plasma mass spectrometer (SF-ICPMS) coupled to the Resonetics laser ablation microprobe (LAM; Fig. 1e).

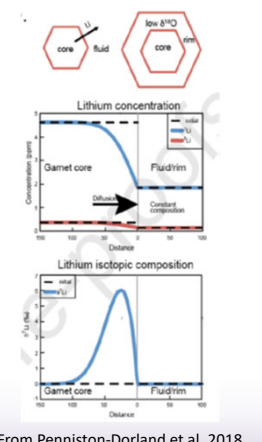
## BSc Project 1

### Constraining timescales of subduction zone processes with in-situ Li isotopes

**Background:** Lithium is a highly mobile light element, and its isotopes are strongly fractionated during diffusion, e.g. when fluids liberated in subduction zones interact with the oceanic crust and Li diffuses from grain boundaries into crystals. This causes variability in Li isotopic composition (denoted as  $\delta^7\text{Li}$ ) at the grain scale (example on right).

**Aims and approach:** Understand the sources and duration of fluid flow events in subduction zones, by determining Li abundances and  $\delta^7\text{Li}$  across garnet and clinopyroxene crystals in eclogite. Because the shapes of the measured Li diffusion profiles depend on the duration of the fluid event, diffusion modelling can be used for time constraints.

**Analytical techniques:** We will characterise garnet-clinopyroxene pairs in 3 representative samples in polished thick sections, using the multi-collector (MC) ICPMS coupled to the Resonetics laser system (Fig. 1e) for  $\delta^7\text{Li}$  and the electron probe for major and minor elements.



From Penniston-Dorland et al. 2018

## MSc Project 2

### Illuminating mass transfer in subduction zones with metal stable isotopes

**Background:** Lithium is a highly mobile light element, and high abundances and distinctive ratios (expressed as  $\delta^7\text{Li}$ ) in crustal reservoirs, yet low abundances in the mantle. Magnesium is moderately fluid-mobile and its isotopes (expressed as  $\delta^{26}\text{Mg}$ ) are strongly fractionated during low-temperature processes. For example,  $\delta^{26}\text{Mg}$  is particularly low in sedimentary carbonate, making this an excellent tracer for the contribution of oxidised carbon in subduction zones, with implications for Earth's carbon cycle.

**Aims and approach:** Unravel with unprecedented detail the interactions of various portions of the slab (sediment, oceanic crust and serpentinised mantle) using a comprehensive stable isotope dataset for samples from eclogites and their altered rinds from the Farallon Plate. This will help identify the agents and mechanisms of element mobility.

**Analytical techniques:** Li and Mg will be isolated from dissolved powders of 10-15 samples using column chromatography in the ultraclean laboratory. Both isotope systems will be analysed using the ThermoFinnigan Neptune Plus multi-collector (MC) ICPMS (Fig. 1e).

## BSc Project 2

### The redox state of Fe in eclogite garnet and oxygen fugacity in deep subduction zones

**Background:** Many mass transfer processes in deep Earth are mediated by fluids and melts as a function not only of composition, pressure, temperature, but also the chemical potential of oxygen, i.e. oxygen fugacity ( $f\text{O}_2$ ). This determines e.g. the stability of S as sulphate ( $\text{SO}_4^{2-}$ ) vs. sulphide ( $\text{HS}^-$ ), which is critical for the mobilisation of ore metals at convergent margins. The redox state of Fe ( $\text{Fe}^{3+}/\Sigma\text{Fe}$ ) is an important parameter to gauge  $f\text{O}_2$ .

**Aims and approach:** Assess the oxygen fugacity and its mineral-scale variability in deep subduction zones by measuring  $\text{Fe}^{3+}/\Sigma\text{Fe}$  in garnet from eclogite in situ.  $f\text{O}_2$  will be calculated using the garnet-clinopyroxene oxybarometer.

**Analytical techniques:** We will determine the Fe oxidation state ( $\text{Fe}^{3+}/\Sigma\text{Fe}$ ) of garnet in 3 representative eclogite samples in polished thick sections using the electron probe microanalyser (Fig. 1e). Major-element compositions of garnet and coexisting clinopyroxene will also be determined, which will provide important context information for the interpretation of  $\text{Fe}^{3+}/\Sigma\text{Fe}$  data.

## Student Assistantships

If you are fascinated by geochemistry and high-temperature processes, become a part of cutting-edge science at Goethe University via a student assistantship that will help you acquire a wide range of skills

### Example tasks:

- Take and process images of geological materials using the optical microscope and the binocular
- Document the microstructure and composition of rocks with electron images using the scanning electron microprobe
- Help with the analysis and data reduction of minerals and rocks using the electron microprobe and mass spectrometer
- Help with the chemical purification of mineral separates and rock powders using column chromatography in the ultraclean laboratory
- Curate databases that form an important baseline for comparison of new sample data to extant literature

## BSc Project 3

### Sulphur mobility in the crust and its implications for the formation of metal ores

**Background:** Eclogite xenoliths from the Navajo Volcanic Field (Fig. 1a) are interpreted as sampling the oceanic crust of the Cretaceous Farallon plate, and were transported to the surface by an unusual water-rich medium emplaced as an ultramafic microbreccia. The eclogites contain abundant pyrite, which is variably altered to a poorly crystalline mass of Fe hydrite (see Fig. on bottom right), indicating S loss during low-temperature alteration at or near the surface.

**Aims and approach:** This study will quantify the proportion of S mobilised using backscatter electron images, and analyse trace-metal concentrations in pyrite and ferrihydrite to investigate to what extent ore-forming metals are mobilised during alteration.

**Analytical techniques:** We will analyse pyrite grains and their ferrihydrite rims in 6 representative samples using the ThermoFinnigan Element XR sector-field inductively-coupled plasma mass spectrometer (SF-ICPMS) coupled to the Resonetics laser system (Fig. 1e).

Backscatter electron image of a pyrite grain partially altered to ferrihydrites

