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Using magnetism to assess the thermal structure of subduction zones

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Key words:	Subduction zones, natural hazards, earthquakes, volcanism, magnetic anomalies, remote sensing
Research theme(s):	• Geophysics and Geodynamics • Geodesy, Tectonics, Volcanology and related hazards
Eligible courses for this project:	• DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILESLA)

Overview

Subduction zones have the potential to host the largest and deepest earthquakes on Earth, posing a significant threat to the communities who live along them from tsunamis and seismic damage to infrastructure (Gardonio et al., 2024). Subduction zones may also host highly explosive volcanism (Sheldrake et al., 2020). Understanding the risk posed by a subduction zone relies upon a good understanding of the thermal structure of the slab in order to accurately constrain friction at the slab interface, and the mantle wedge to understand the composition of generated magmas (Turner et al., 2016).

One way to estimate the thermal structure of subduction zones is by examining the crustal magnetic anomalies that overly the region. Some studies have attempted to use 'Curie point depths', the depth at which magnetic minerals such as magnetite lose their magnetization (Manea and Manea, 2011). However, the behaviour of magnetic anomalies is found to vary significantly between subduction zones (Choe and Dyment, 2021). It has been argued that this could be due to pressure-driven alteration and demagnetization of minerals in the subducting slab (Han et al., 2023), or due to compositional variation in magnetic carriers and the development of strong petrographic fabrics (Li et al., 2025).

In this project, we will work on a suite of samples that represent mantle wedge, slab and sedimentary material that has been exhumed from ancient subduction zones. The project will focus on linking the petrology and rock magnetic signatures to understand the dominant controls on surface magnetic anomalies. This work can then be applied to modern subduction zones by examining their physical properties (seismic activity, magnetic anomalies, heat flow etc) to reconcile apparent Curie point depths with processes occurring along the slab interface and within the mantle wedge.

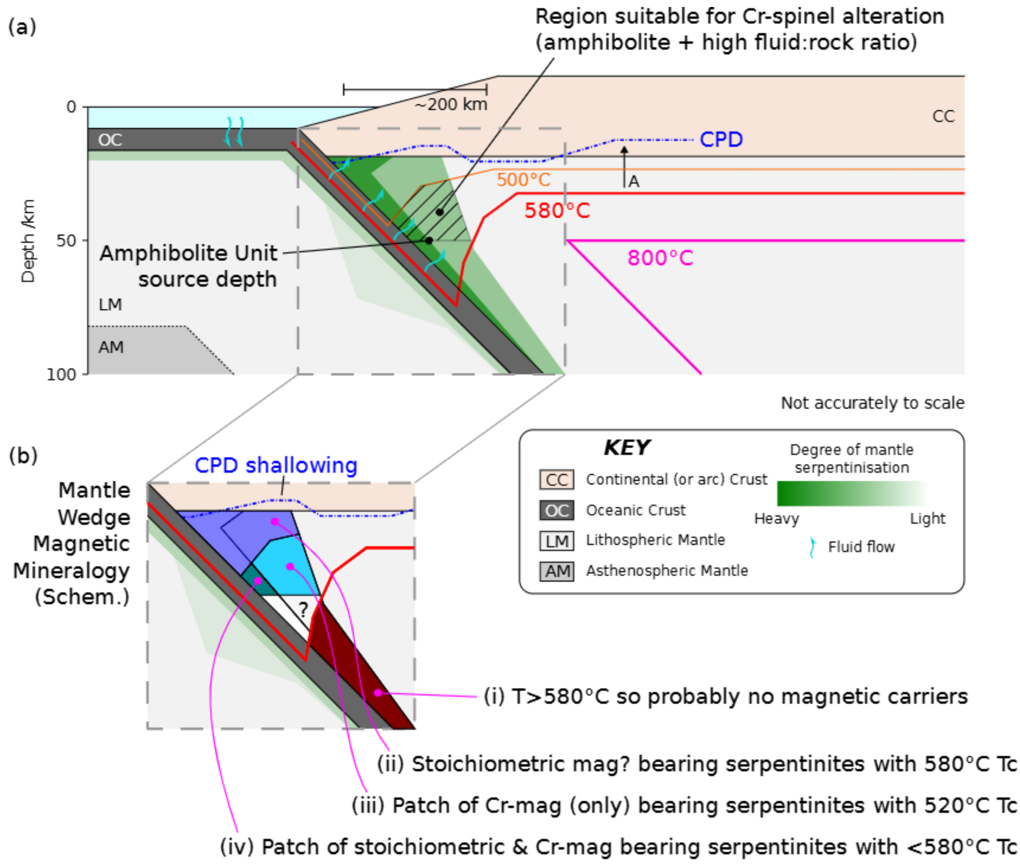

Figure showing how petrological fabric development and changes in magnetite composition can influence Curie point depths (taken from Li et al., 2025).

Methodology

The project will involve examining existing samples from Catalina Island (California) and Japan that represent exhumed material from subduction zones. The petrology of samples will be characterized using an optical microscope and the SEM. The magnetic properties will be analysed using the quantum diamond microscope (QDM). There will be scope to carry out future fieldwork to promising locations identified during the project. Results will be synthesized to inform models to predict the thermal structure, role of hydrothermal circulation and hydration in subduction zones around the world.

Timeline

Year 1: The student will undertake a literature review on all existing work on magnetism in subduction zones. They will look at existing samples and collect preliminary SEM and QDM data. They will receive all necessary training on how to use these facilities. A paper draft is expected by the end of the first year.

Years 2 and 3: The student will continue their sample analysis, and if necessary will help to design and plan fieldwork to collect additional samples. They will learn how to create simple subduction zone models to understand the implications of their results for using magnetic anomalies to interpret subduction zone thermal structure. The student will present results at both national and international conferences. One to two papers should be submitted for publication by the end of the third year.

Year 4: The student will finish modelling work, and results will be summarised during thesis writing, and any additional papers submitted for publication. Results will be presented at an international conference, with a focus on networking and future career steps.

Training & Skills

- Rock magnetism
- Petrology and electron microscopy
- Geological fieldwork
- Seismology
- Coding (Python)
- Scientific writing and presenting

References & Further Reading

Choe, H., Dyment, J., 2021. The fate of marine magnetic anomaly in subduction zones: A global appraisal. Earth Planet. Sci. Lett. 561, 116787. https://doi.org/10.1016/j.epsl.2021.116787

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Turner, S.J., Langmuir, C.H., Katz, R.F., Dungan, M.A., Escrig, S., 2016. Parental arc magma compositions dominantly controlled by mantle-wedge thermal structure. Nat. Geosci. 9, 772–776. https://doi.org/10.1038/ngeo2788

Further Information

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