EARTHSCIENCES

$CaSiO_3$ perovskite in Earth's deep mantle

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Key words:	
Research theme(s):	• Geophysics and Geodynamics • Planetary Evolution and Materials
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP)

Overview

$CaSiO_3$ Davemaoite is a high-pressure and high-temperature calcium silicate perovskite mineral with a cubic crystal structure (Tschauner et al., 2021). It is expected to be the third most abundant mineral in the Earth's lower mantle. Sound velocity measurements found that Davemaoite has lower seismic wave velocities than other major mantle minerals, and Davemaoite-bearing subducted oceanic crust may cause the observed low-seismic structures in the mantle (e.g. Thomson et al, 2019). Furthermore, Davemaoite is likely the weakest lower-mantle phase, controlling the dynamics of the slab subduction process (Immoor et al., 2022).

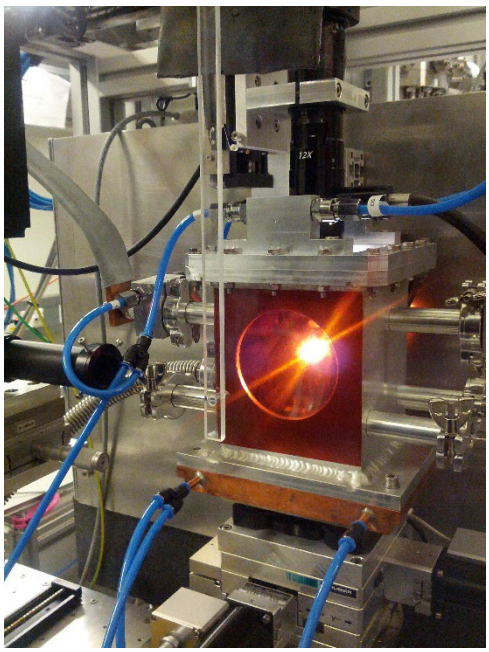

Figure shows experimental setup for high-pressure/-temperature experiments on $CaSiO_3$ at the Extreme Conditions Beamline P02.2 at DESY, Germany.

Despite the importance of understanding the physical and chemical properties of Davemaoite in the lower mantle, the phase stability of this mineral in the lower mantle is poorly constrained, particularly the phase transition to its tetragonal counterpart. A recent study suggested that the cubic-tetragonal phase might intersect with the pressure-temperature path in "cold" subducted slabs (Thomson et al., 2019).

This project is motivated by controversy around the position of the cubic-tetragonal phase boundary of Davemaoite in the lower mantle, which is pivotal to (1) understand its role in explaining seismic observables in the lower mantle, as well as (2) quantifying its importance for understanding slab dynamics and slab delamination. The results from this project will have major impacts on our understanding of

the seismic signature of Davemaoite in the lower mantle, the dynamic behavior of subducting slabs, and future research aiming to quantify chemical heterogeneity in the deep mantle from seismic tomography.

Methodology

$CaSiO_3$ and $Ca(Si_{0.9}Ti_{0.1})O_3$ perovskite/davemaoite will be synthesized in situ from glass starting material employing a state-of-the-art resistive-heated Diamond-Anvil Cell (DAC) at high-pressure and -temperature (Immoor et al., 2022). Time-resolved X-ray diffraction (XRD) will be recorded in-situ using Synchrotron radiation at the German Synchrotron Radiation Facility DESY and at Diamond Light Source (UK) (e.g. Trautner et al., 2023). This novel approach will allow us to pinpoint the cubic-tetragonal phase boundary in $CaSiO_3$ and $Ca(Si_{0.9}Ti_{0.1})O_3$ perovskites with unprecedented details as well as study the elastic behavior across the phase transition.

Timeline

Year 1: Literature review, planning of experimental campaigns, application for synchrotron beamtime, introduction to methodology.

Years 2 and 3: High-pressure/-temperature experiments, data analysis, geophysical modelling, presentation of research at international conferences.

Year 4: Data integration, thesis completion, papers for international journals/conferences.

Training & Skills

As part of this project you will learn how to prepare diamond-anvil cells, conduct high-pressure/-temperature experiments using time-resolved XRD at Synchrotron sources. You will also receive training in data analysis and how to apply laboratory data to interpret real world geophysical observations. You will also receive training in presenting scientific results, and writing scientific papers.

References & Further Reading

Immoor, J., L. Miyagi, H. P. Liermann, S. Speziale, K. Schulze, J. Buchen, A. Kurnosov and H. Marquardt, Weak cubic CaSiO3 perovskite in the Earth's mantle. Nature 603(7900) (2022): 276-279.

Thomson, A., W. Crichton, J. Brodholt, I. Wood, N. Siersch, J. Muir, D. Dobson and S. Hunt. Calcium silicate perovskite's acoustic velocities can explain LLSVPs in Earth's lower mantle. Nature 572 (2019): 643-647.

Trautner, V. E., S. Stackhouse, A. R. Turner, P. Koelemeijer, D. R. Davies, A. S. J. Méndez, N. Satta, A. Kurnosov, H.-P. Liermann and H. Marquardt, Compressibility of ferropericlase at high-temperature: Evidence for the iron spin crossover in seismic tomography. Earth and Planetary Science Letters 618 (2023): 118296.

Tschauner, O., S. Huang, S. Yang, M. Humayun, W. Liu, S. N. G. Corder, H. A. Bechtel, J. Tischler and G. R. Rossman, Discovery of davemaoite, $CaSiO_3$-perovskite, as a mineral from the lower mantle. Science 374(6569) (2021): 891-894.

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