Report for the Joint Use/Research of the Institute for Planetary Materials, Okayama University for FY2024

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Category: ☑International Joint Research ☐General Joint Research ☐Joint Use of Facility ☐Workshop

Name of the research project: Rheology of the CF phase and fate of subducting MORB

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Collaborator

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Research report:

Basalt transforms to its lower-mantle mineral assemblage of bridgmanite ~25%, stishovite~20%, davemaoite~20%, calcium ferrite, 25% and the NAL phase ~5% between 660 and 800 km depth, the region where it is neutrally buoyant in the mantle. We know the rheology of bridgmanite (stiff) and davemaoite (soft) and stishovite is very likely to be similar to bridgmanite. In this case, the rheology of basalt is likely to depend critically on F strength – if CF is strong davemaoite will be isolated and basalt rheology will be dominated by the strong minerals but if CF is weak then between them CF and davemaoite will form a weak interconnected network and basalt will be weak. This in turn controls the fate of subducted oceanic crust, MORB – whether it ponds below 660 km depth, founders to the core-mantle boundary or becomes entrained in upwelling plumes critically depends on the relative strength of MORB and lower-mantle peridotite.

We measured the rheology of the CF phase using in-situ synchrotron MA deformation experiments at Spring-8. Samples were synthesized at 22 GPa in the MA presses and characterized by XRD and SEM at Misasa. Dobson and Xu performed the experiments during a visit to Misasa for 1 month in July 2024, with periodic visits to SPring-8. Ishii and Xu synthesized the samples together.

Results for CF are shown in figure 1. CF deforms by dislocation creep (confirmed by stress exponent n=2.99; CPO development and grain-size insensitive rheology.) with an activation enthalpy of 506 kJ/mol. This large activation volume means CF phase is similar in strength to bridgmanite when cool in subducting slabs, but it becomes substantially weaker than bridgmanite in upwelling plumes (Figure 2). This results in a transition in MORB from strong to weak behaviour at temperatures of upwelling plumes. These results are in preparation for submission to Nature Geoscience.

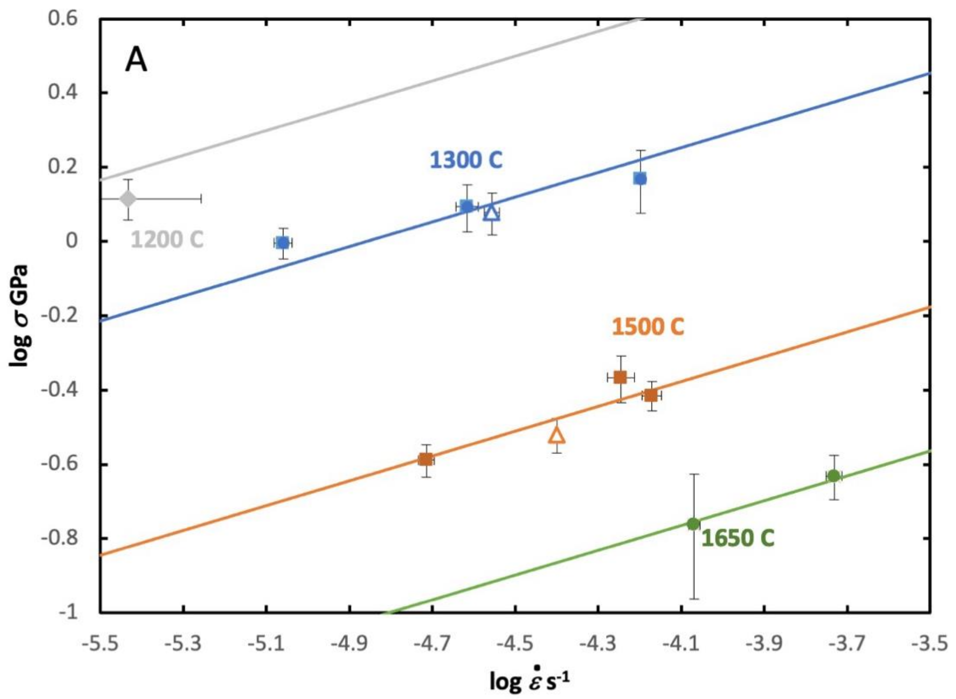

Figure 1. Measured rheology of CF phase.

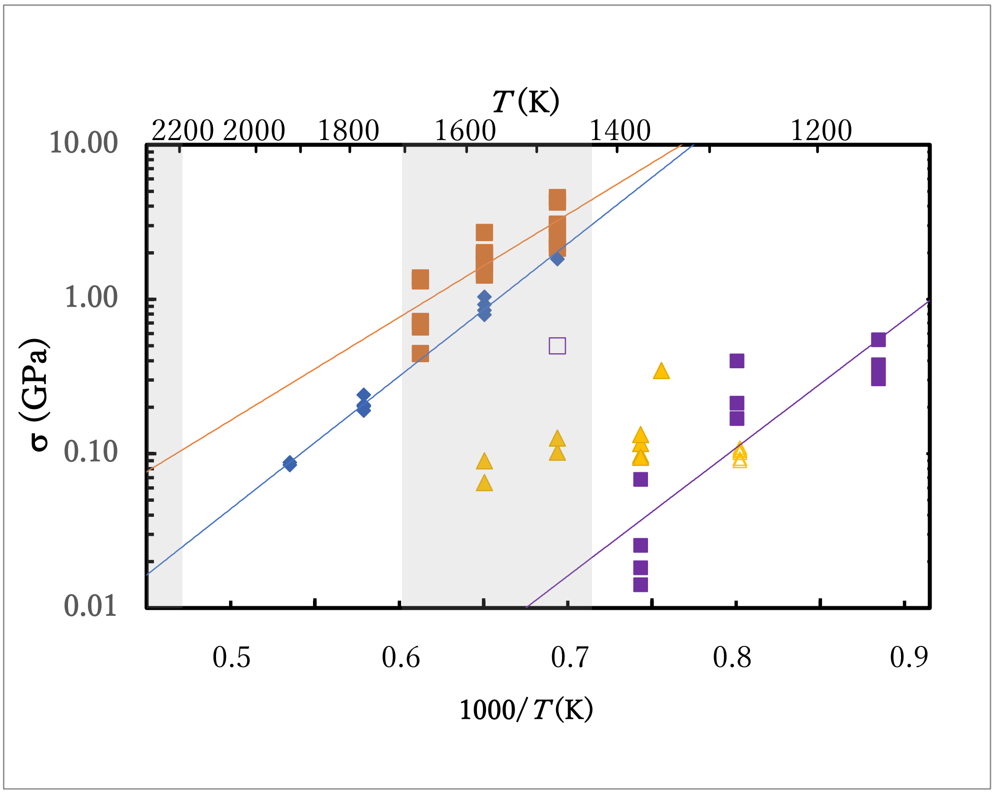

Figure 2. Rheology of the main lower-mantle minerals. Blue diamonds – CF; brown squares – bridgmanite; purple squares – davemaoite; yellow triangles – ferropericlase. CF has the same strength as bm at 1300 K but is 5 times weaker at 2200 K. This results in a significant reduction in

MORB viscosity (Figure 3).

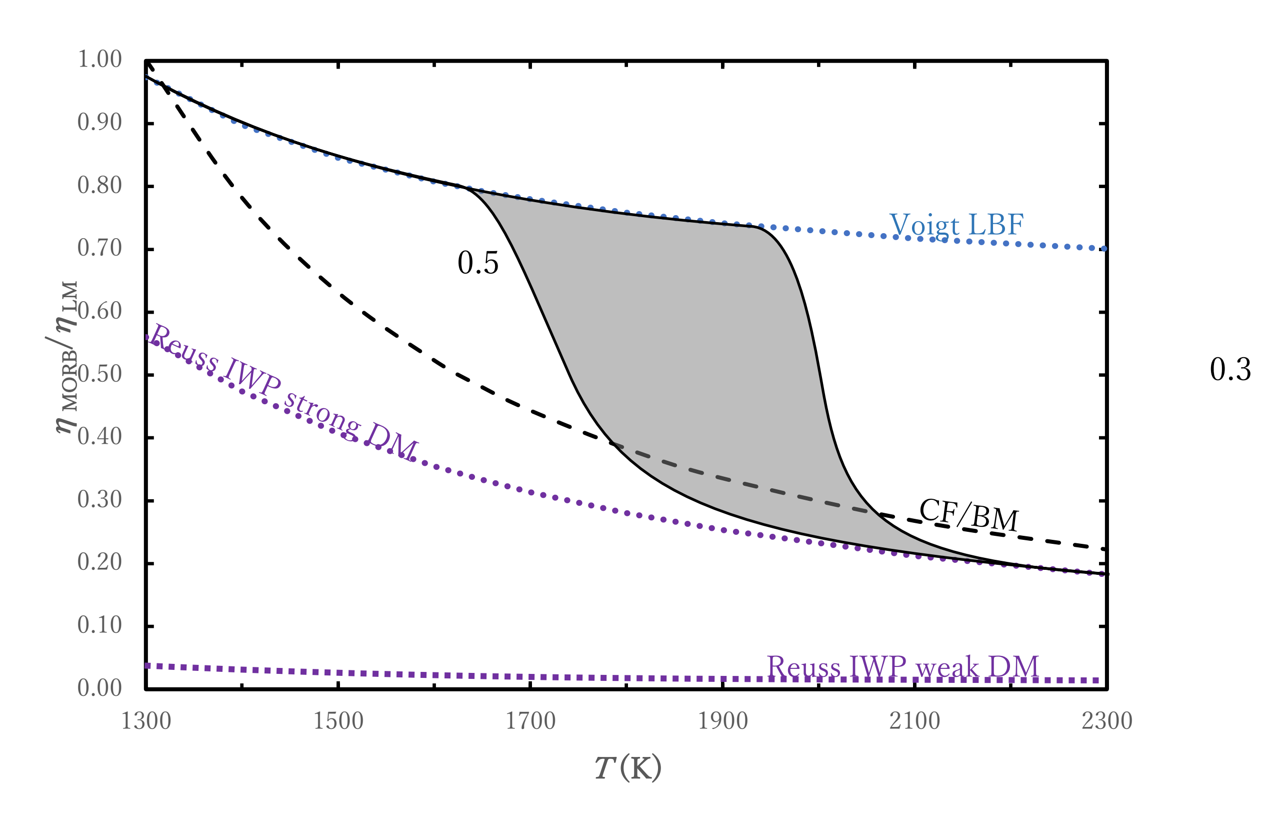

Figure 3. Relative strength of MORB and lower-mantle peridotite as a function of temperature. As CF weakens there is a transition from strong, load-bearing-framework behaviour (Voigt bound) to interconnected-weak-phase behaviour (Reuss bound), resulting in MORB becoming 7-50 times weaker than peridotite in upwelling plumes.