



Toward a better understanding of the thermochemical evolution in Earth and planetary interiors

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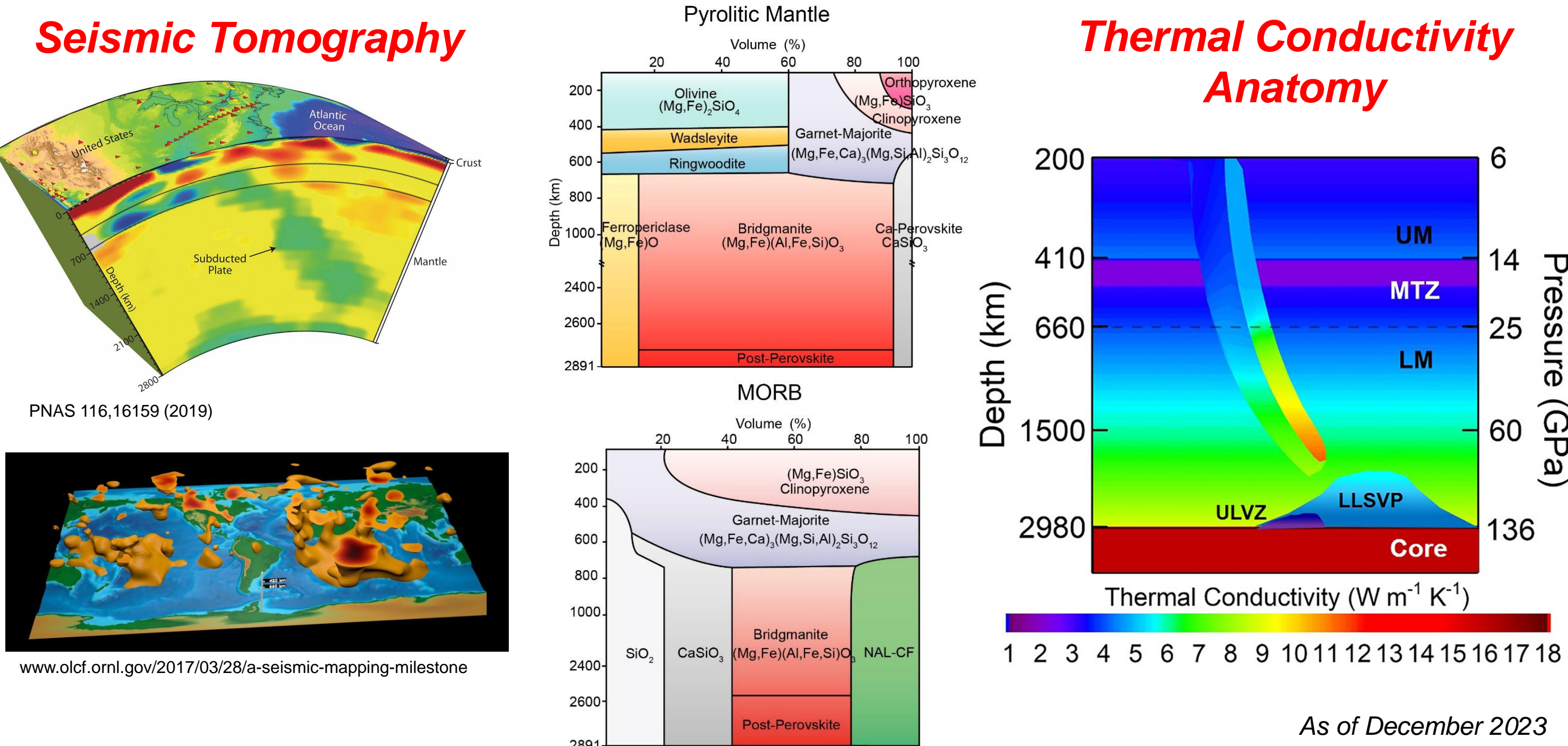
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Introduction

Transport properties of constituting materials in Earth and planetary interiors play critical roles in controlling their thermochemical evolution and dynamics. Thermal conductivity is one of the key transport properties, in particular around the regions where heat is predominantly transferred by conduction, such as near the thermal boundary layers. Recent successful coupling of an ultrafast optical pump-probe method with externally- and laser-heated diamond anvil cells have enabled us to systematically and precisely measured the thermal conductivity of deep Earth materials, from upper mantle all the way down to the core. Combined with data modelling, we have created the first deep Earth thermal conductivity anatomy, including pyrolytic mantle, subducting slab, and heterogeneous structures in Earth's deep interior, which has critical impacts on the thermochemical evolution and geodynamics in different regions.

A journey to the center of the Earth

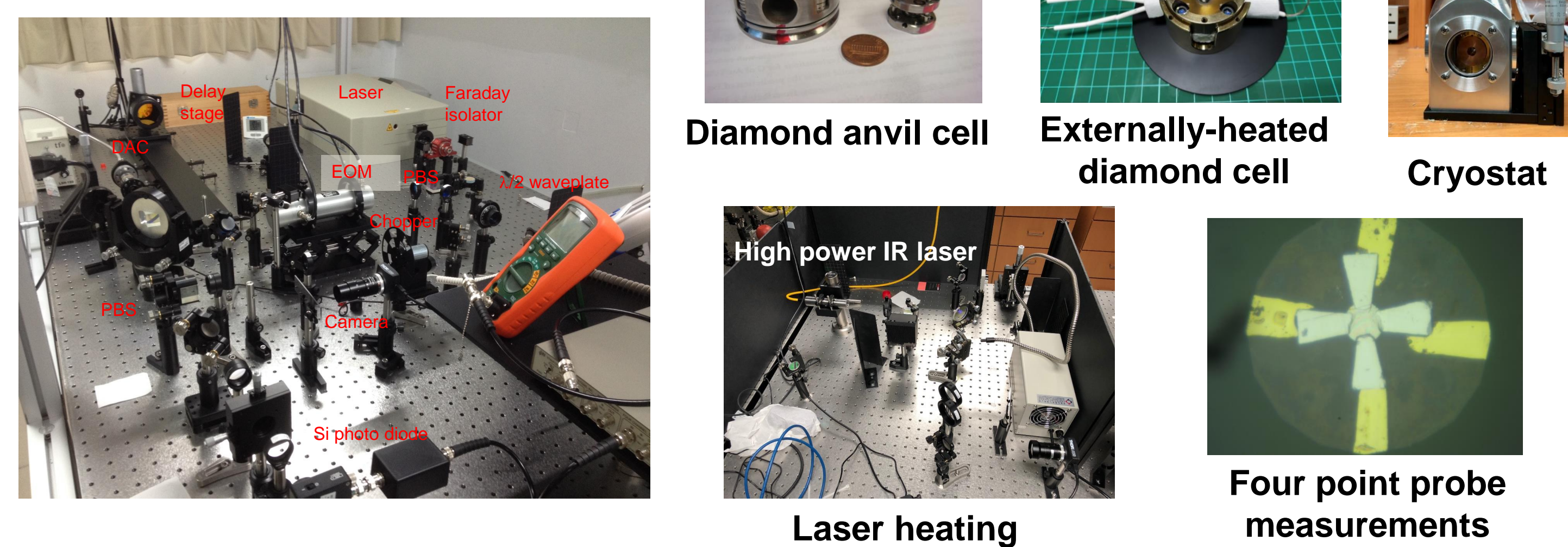
Mapping the thermal profile in Earth's interior: Deep Earth Thermal Conductivity Anatomy (DETCA)



Thermal conductivity of Earth materials is key to control the temperature profile, thermal evolution, thermochemical structures, and dynamics of Earth interior.

Ultrafast optical pump-probe spectroscopy coupled with high-pressure diamond cells and high-temperature heating or low-temperature cooling

Ultrafast optical pump-probe measurements at Academia Sinica



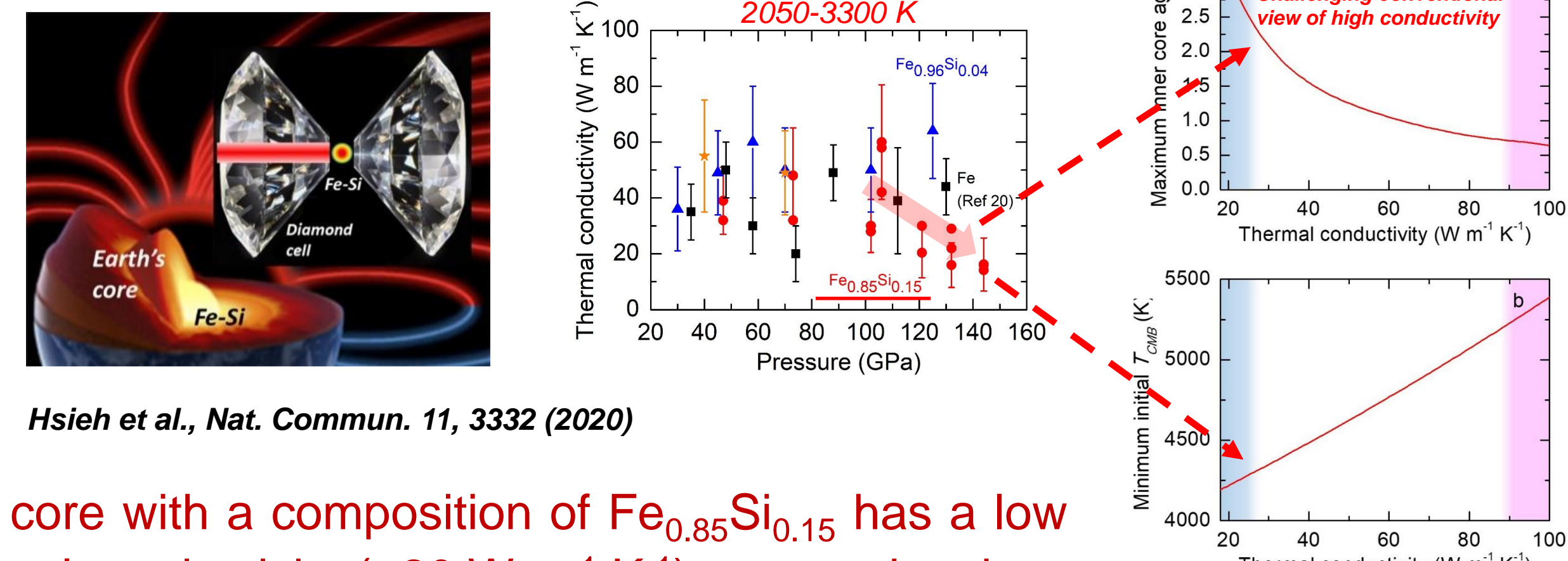
Time-domain thermoreflectance, four point probe technique + diamond cell with heating/cooling

enable measurements of thermal and electrical conductivity and elastic constants at high pressures and variable temperatures

- General for almost all samples/minerals
- Measurements at extreme P , T , t , and chemical compositions

Discovering anomalous thermal structures in deep Earth, fundamentally changing our understanding of Earth's thermochemical structure and evolution history

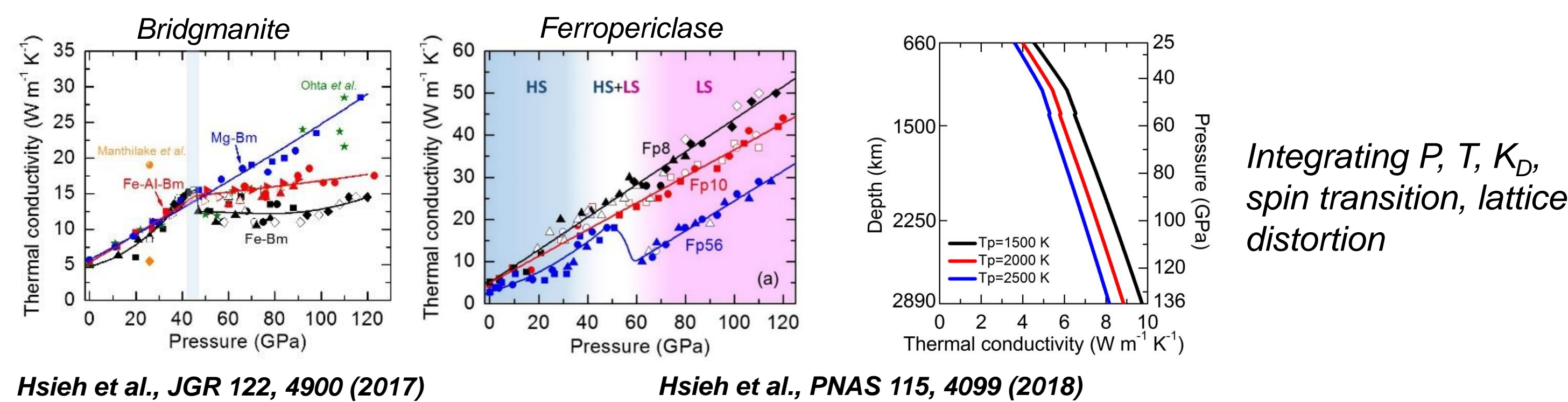
Earth's core



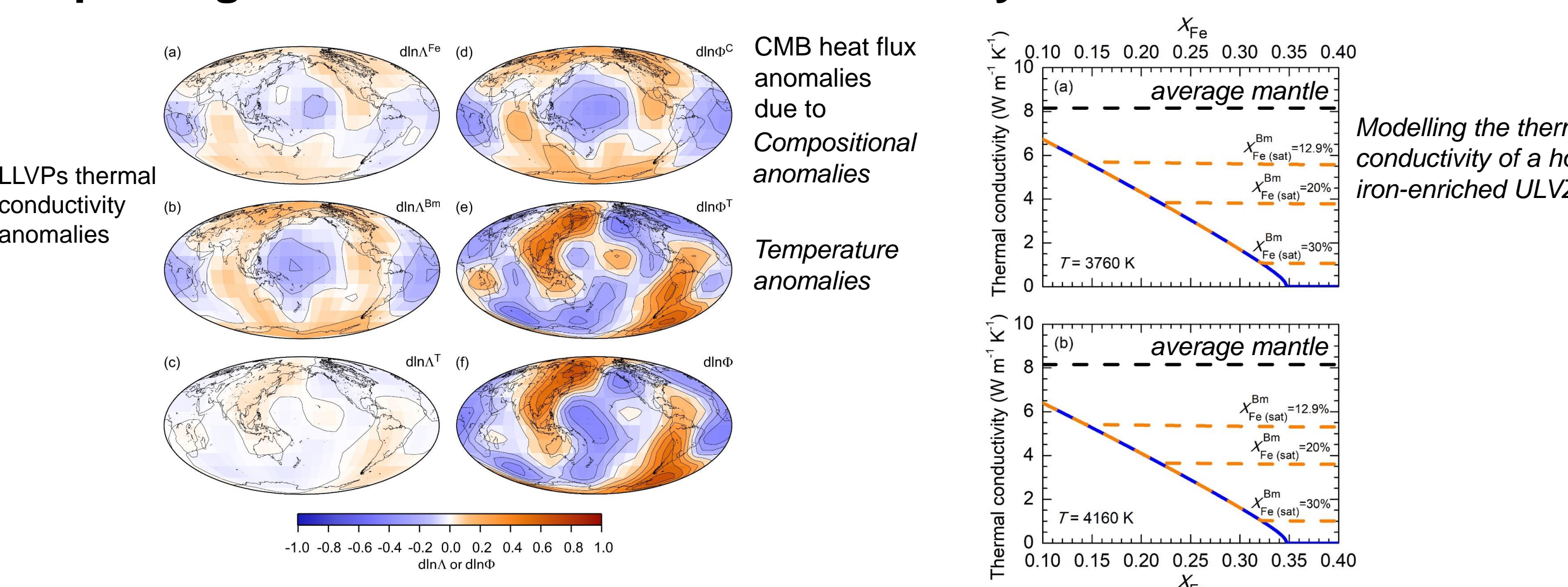
The core with a composition of $\text{Fe}_{0.85}\text{Si}_{0.15}$ has a low thermal conductivity ($\sim 20 \text{ W m}^{-1} \text{ K}^{-1}$), suggesting that

- the max age of inner core could be 2 Gyrs, much older than previously thought.
- the thermal energy alone could be enough to operate the geodynamo and sustain Earth's magnetic field: Q_{CMB} , $\sim 10 \text{ TW}$, is larger than Q_a , the isentropic heat flow through the core.

Lower mantle



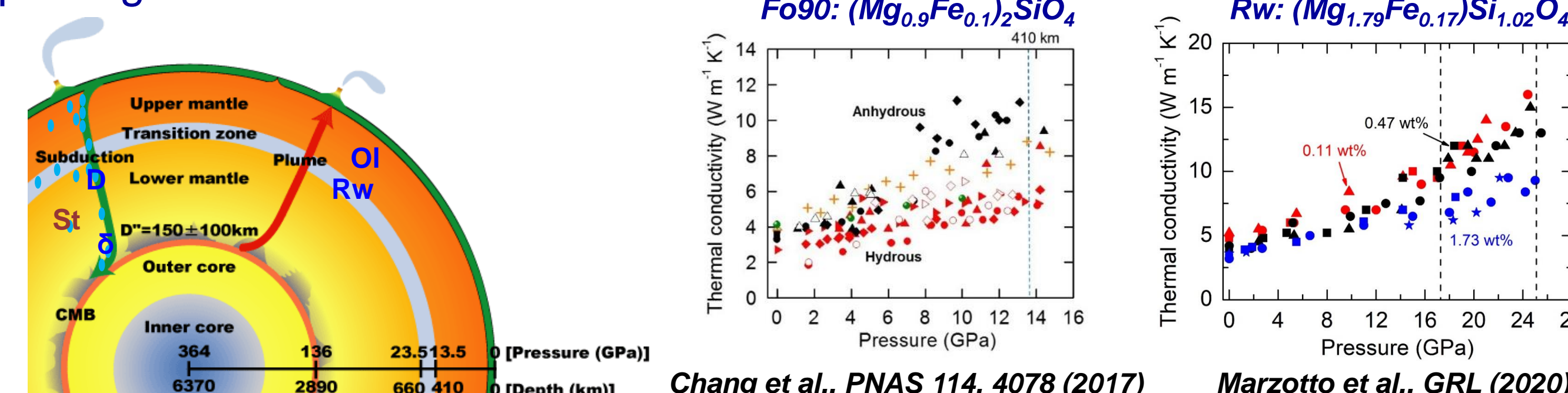
Impacting lower mantle thermal conductivity and thermal evolution



- Presence of Fe and Al has strong effects on the thermal conductivity of bridgmanite and ferropericlase under relevant high P - T conditions.
- The LLVPs' thermal conductivity and CMB heat flux are influenced accordingly.
- Above the CMB, iron-enriched mantle aggregates not only have ultra-low seismic velocity, but also ultra-low thermal conductivity ($\sim 30\%$ to 80% lower than the average mantle). This would lead to a high temperature anomaly, affecting the rheology and dynamics at both sides of the CMB.

Upper mantle

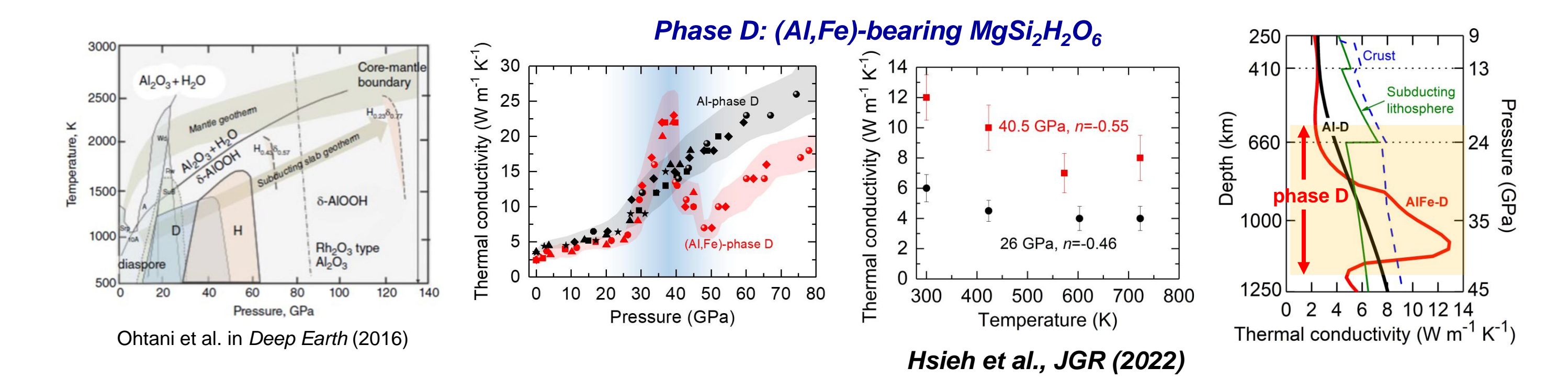
Earth's deep water cycle makes some minerals hydrated, resulting in poor heat conduction and low temperature anomaly, preserving hydrous minerals and impacting seismic structures.



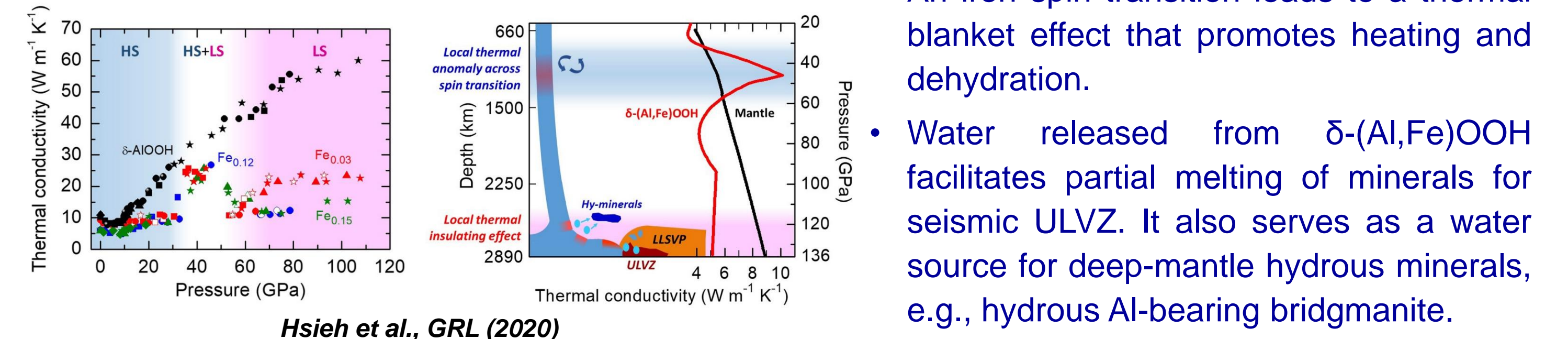
Acknowledgements

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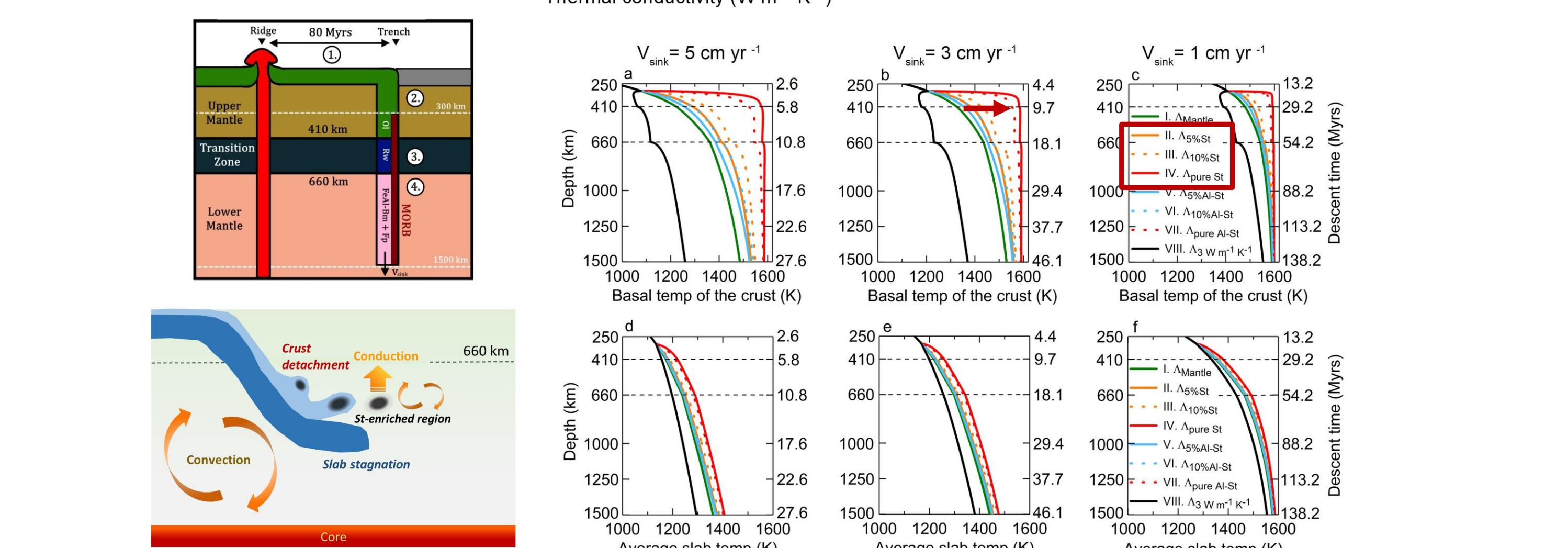
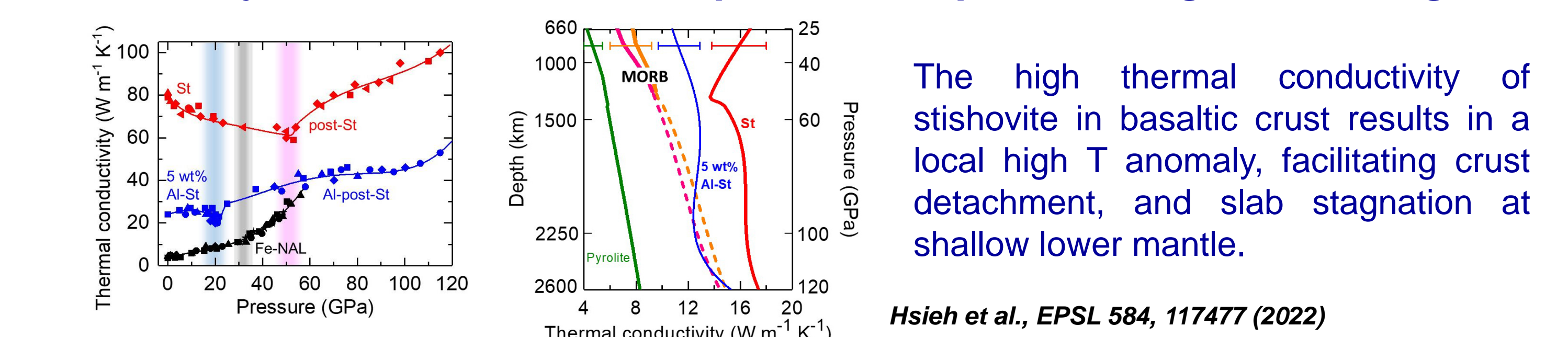
Phase D is a potential water carrier to transition zone and shallow lower mantle



δ -(Al,Fe)OOH is stable at lowermost mantle conditions: a candidate to transport water to the bottom of the mantle

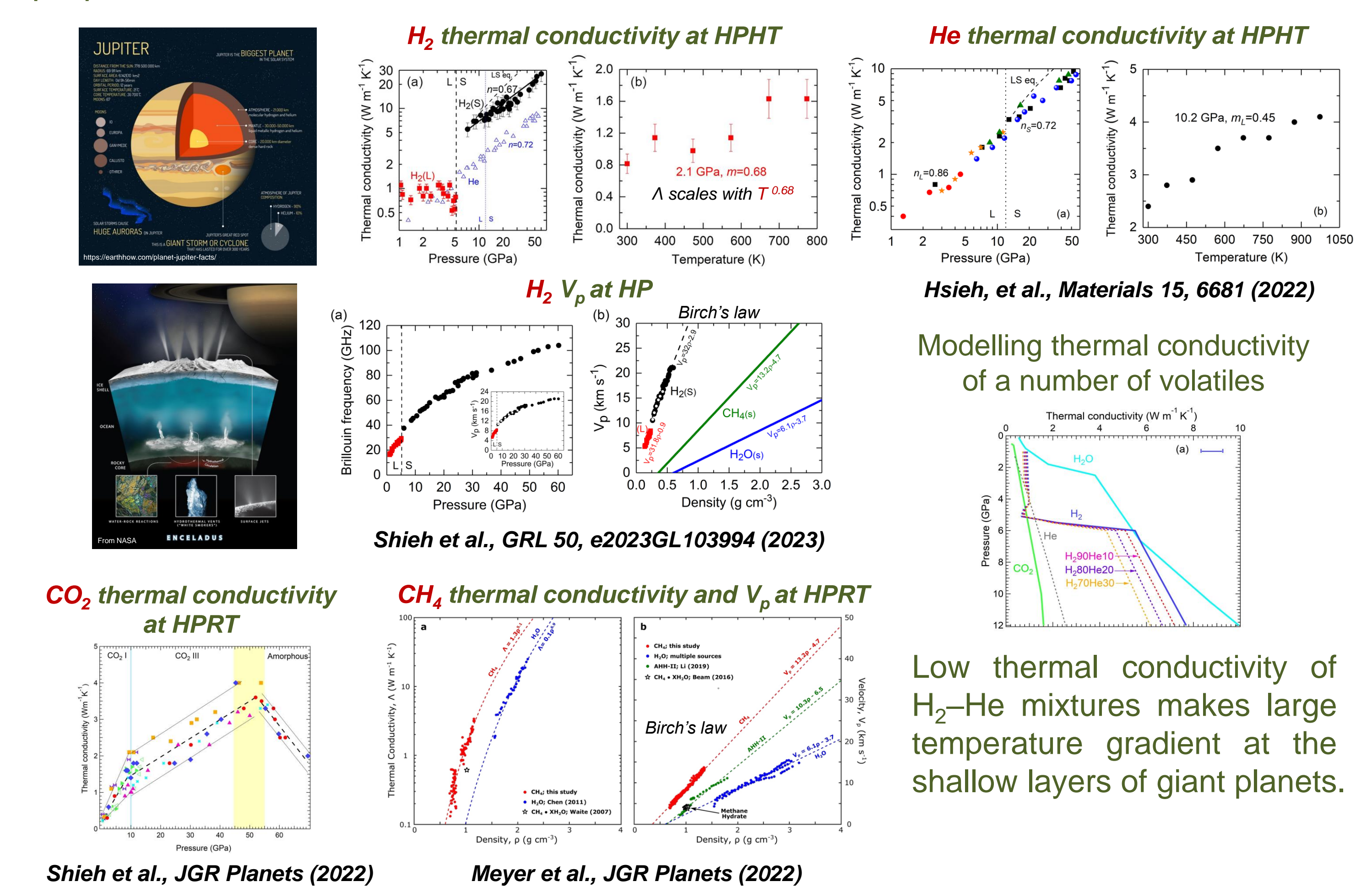


A thermally conductive stishovite promotes rapid warming of a sinking slab



Planetary interiors

Volatiles in giant planets and icy bodies critically affect their physical and chemical properties and thermochemical evolution



Summary

- Thermal conductivity of materials in Earth and planetary interiors plays key roles in influencing their thermochemical evolution.
- Future HPHT and HPLT data are required to further pin down the thermal transport properties with relevant applications.
- Further combinations of transport properties and numerical modelling will offer novel insights to the dynamics and evolution in Earth and planetary interiors.