Low thermal conductivity of Earth's core with implications for the geodynamo and the age of inner core

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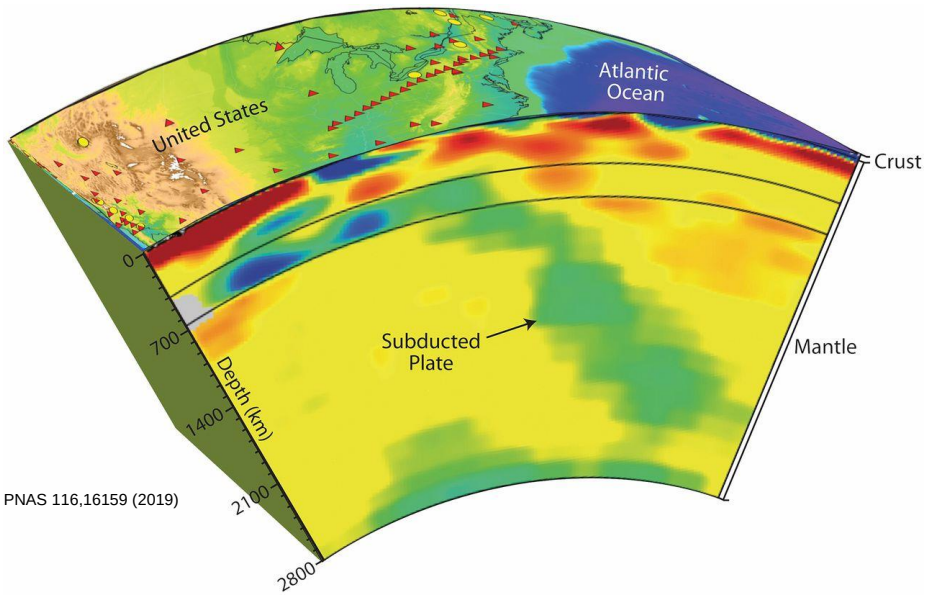
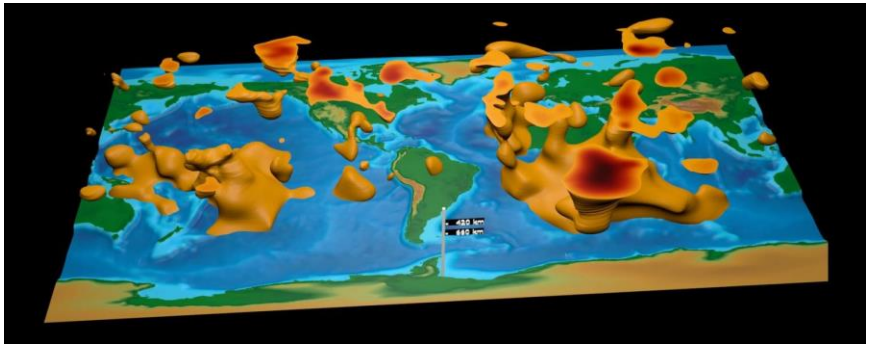
and many others…

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

Seismic Tomography

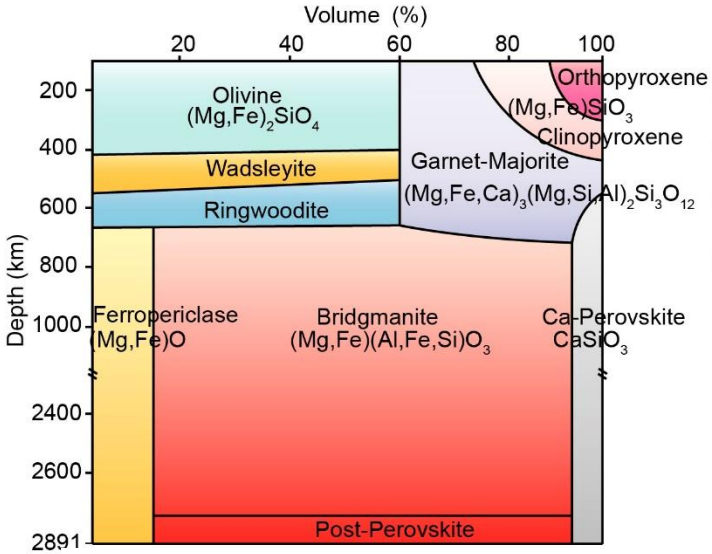


PNAS 116,16159 (2019)

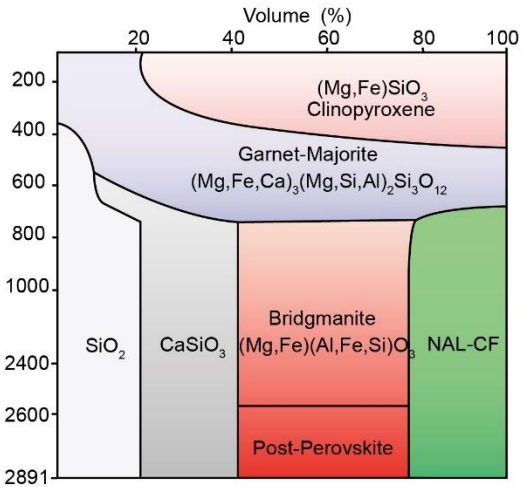


www.olcf.ornl.gov/2017/03/28/a-seismic-mapping-milestone

Pyrolitic Mantle

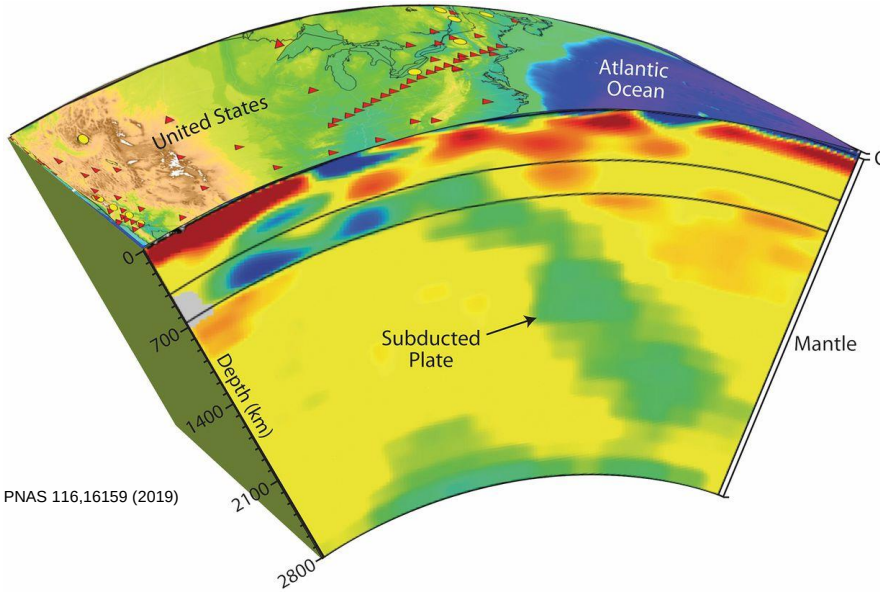


MORB



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

Seismic Tomography



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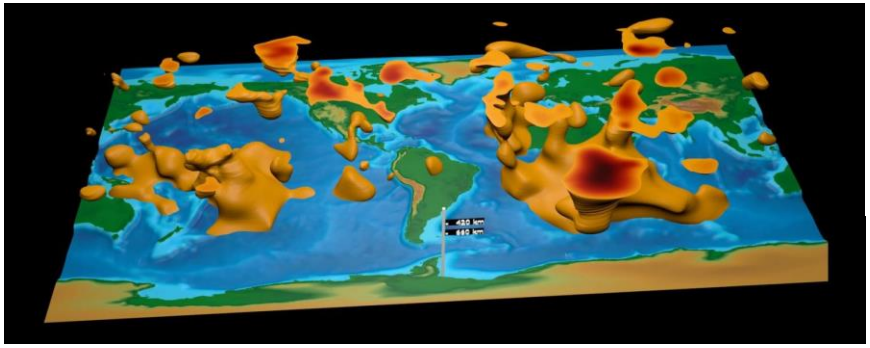

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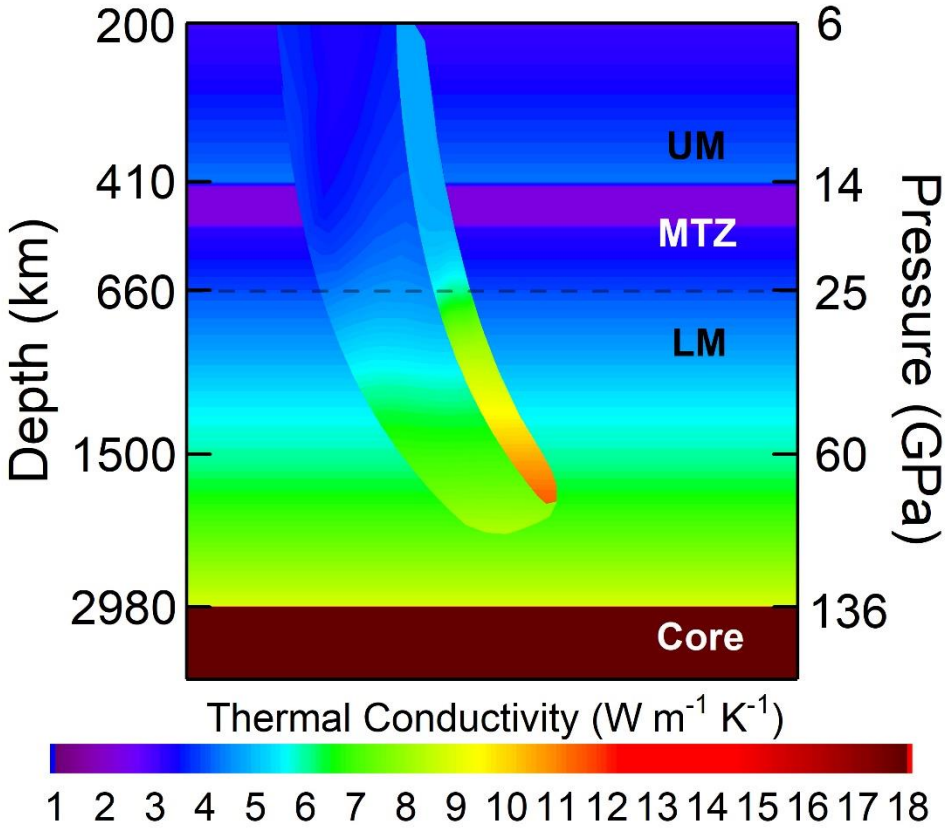
Thermal Conductivity Anatomy

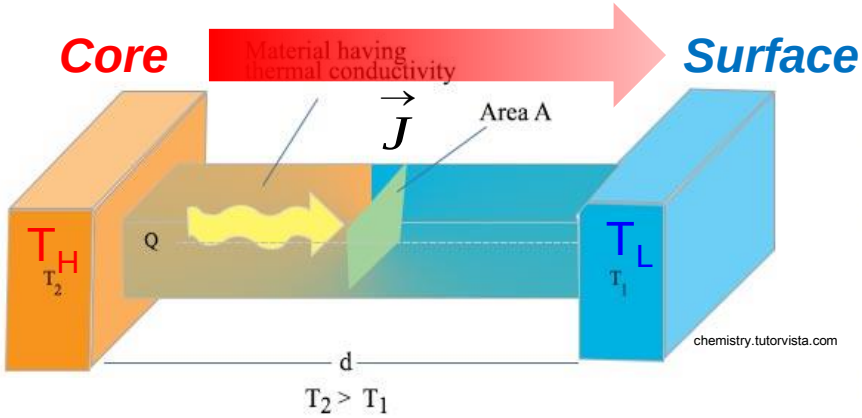


As of April 2021

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

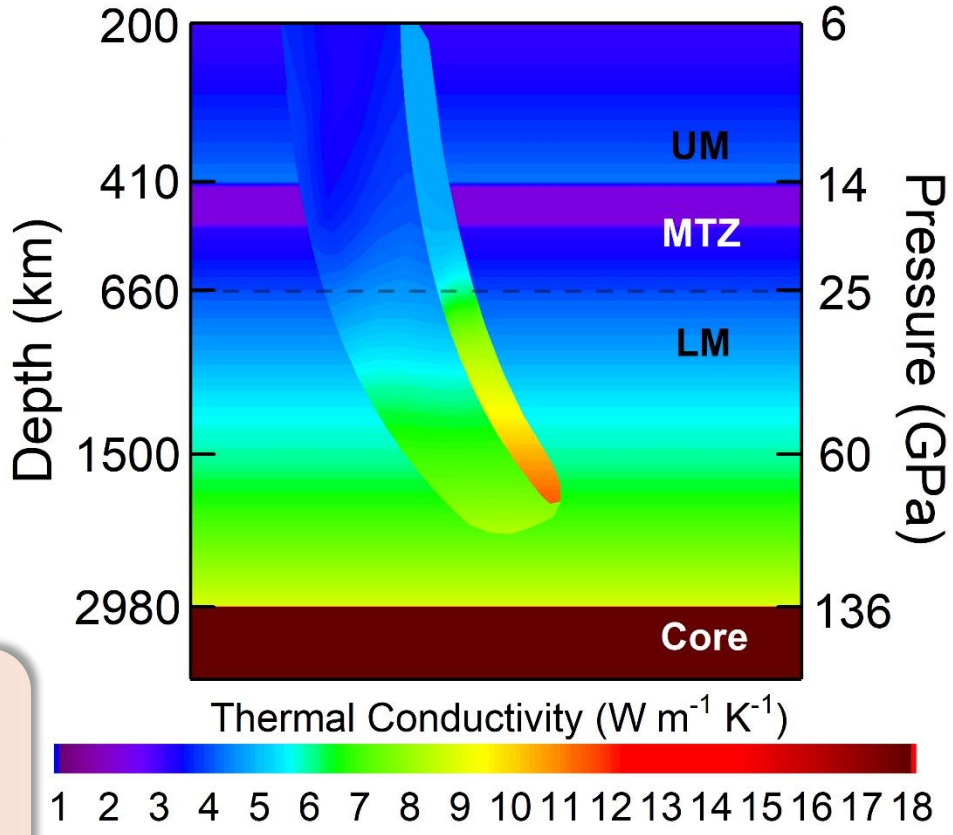
Thermal conductivity Λ :

ability to conduct heat



$$\vec{J} = -\Lambda \vec{\nabla} T$$

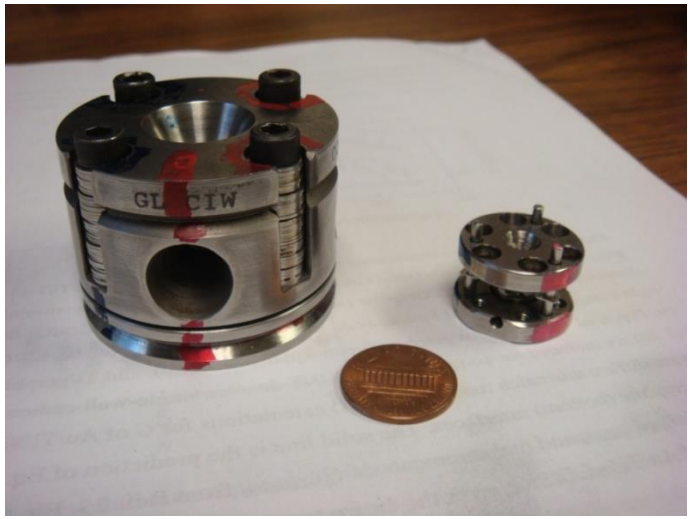
Thermal Conductivity Anatomy

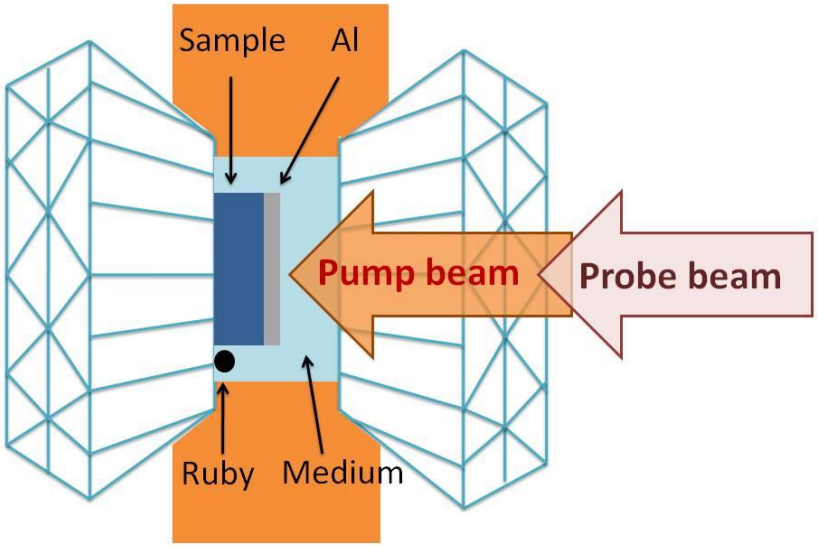


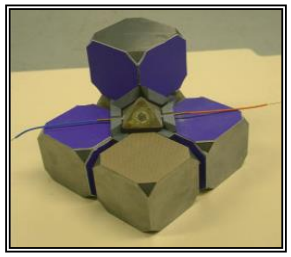
Thermal conductivity of Earth materials is key to control the temperature profile, thermal evolution, thermo-chemical structures, and dynamics of Earth interior

As of April 2021

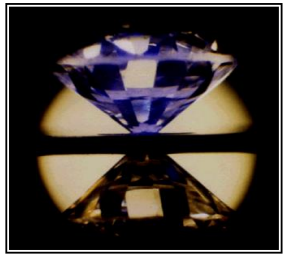
Combine ultrafast pump-probe with diamond cells to precisely measure thermal conductivity under extremes



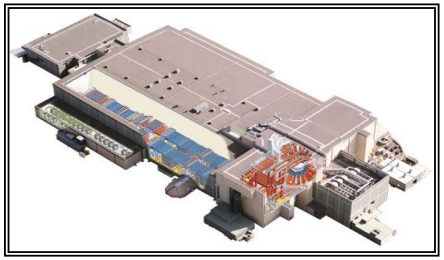




Multi-Anvil



DAC



Lasers

D" CMB

135 GPa

Earth's Core

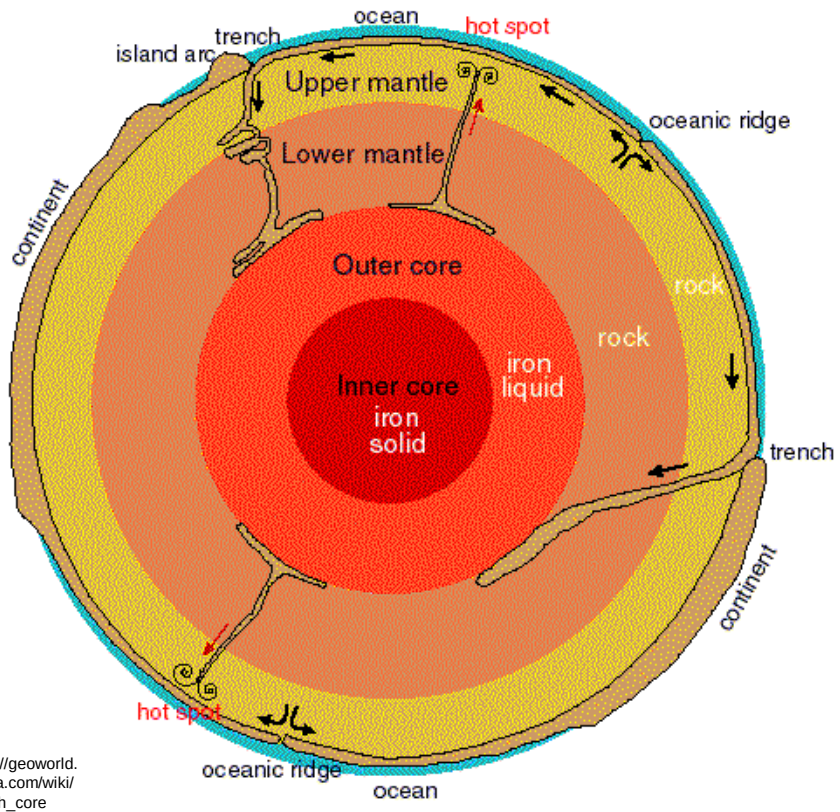
360 GPa

~10 GPa

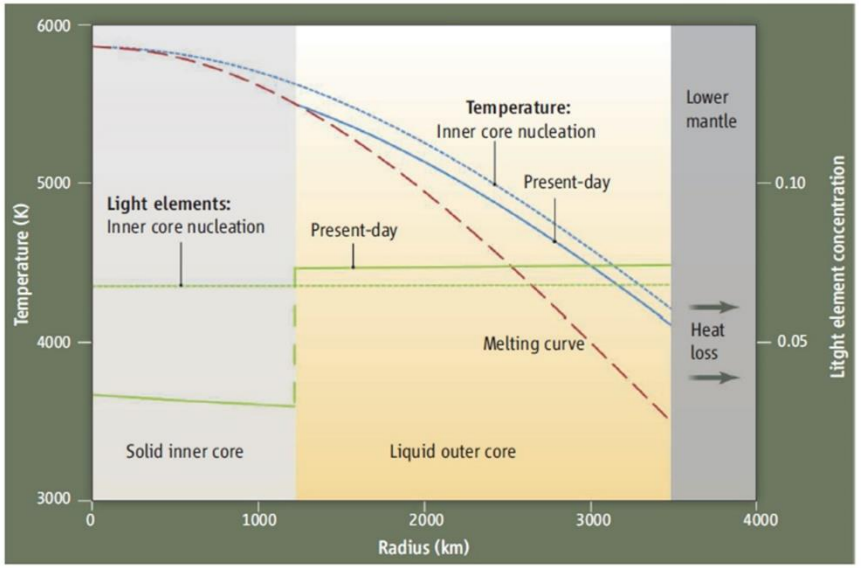
~100 GPa

>>10^3 GPa

Hi **Inner Core**, how old are you?



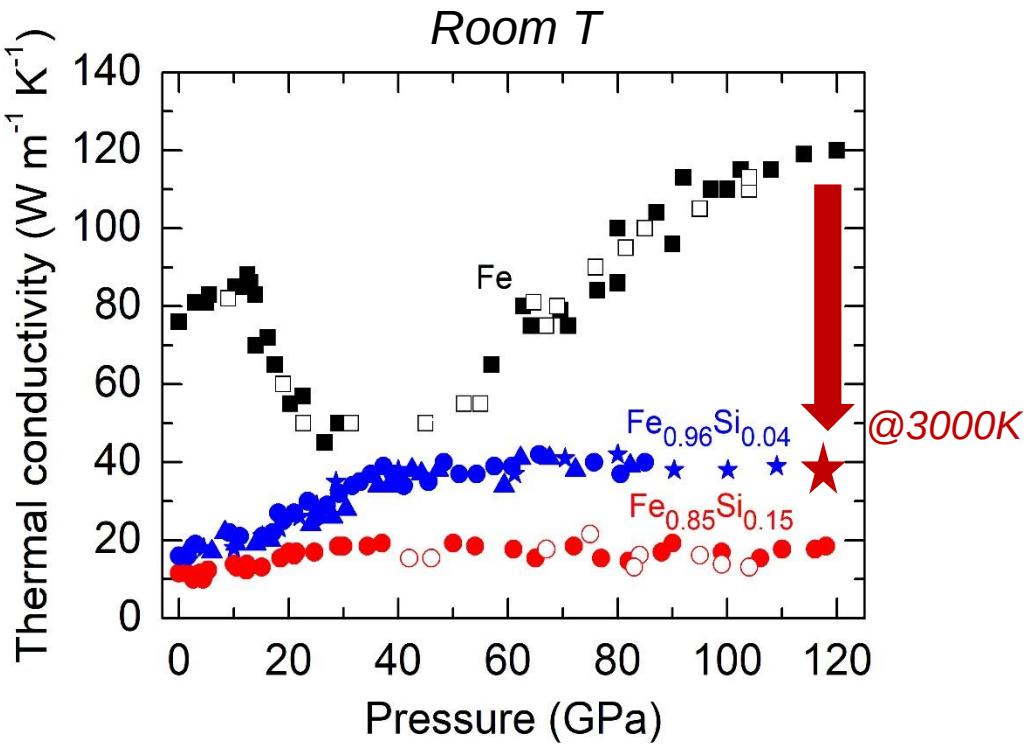
http://geoworld.wikia.com/wiki/Earth_core



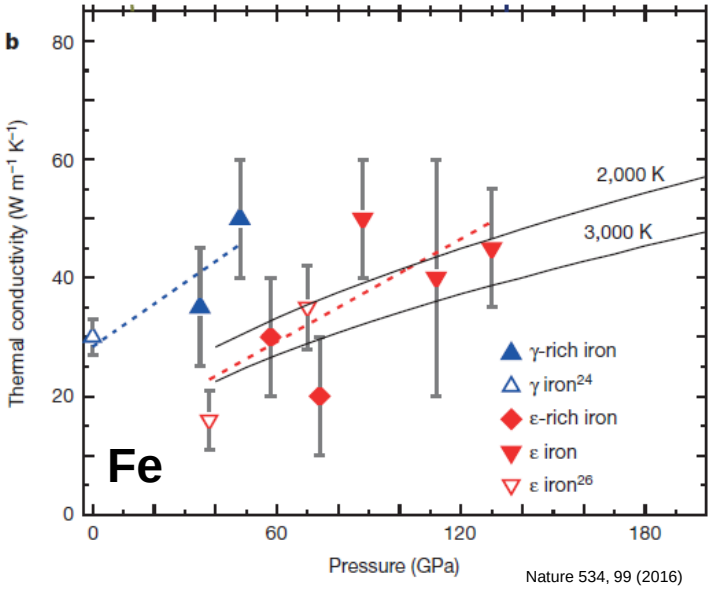
Science 342, 431 (2013)

The lower the thermal conductivity, the slower the cooling: ***inner core is older***

Lower core thermal conductivity delays cooling and powers dynamo



Prior studies were contradictory…

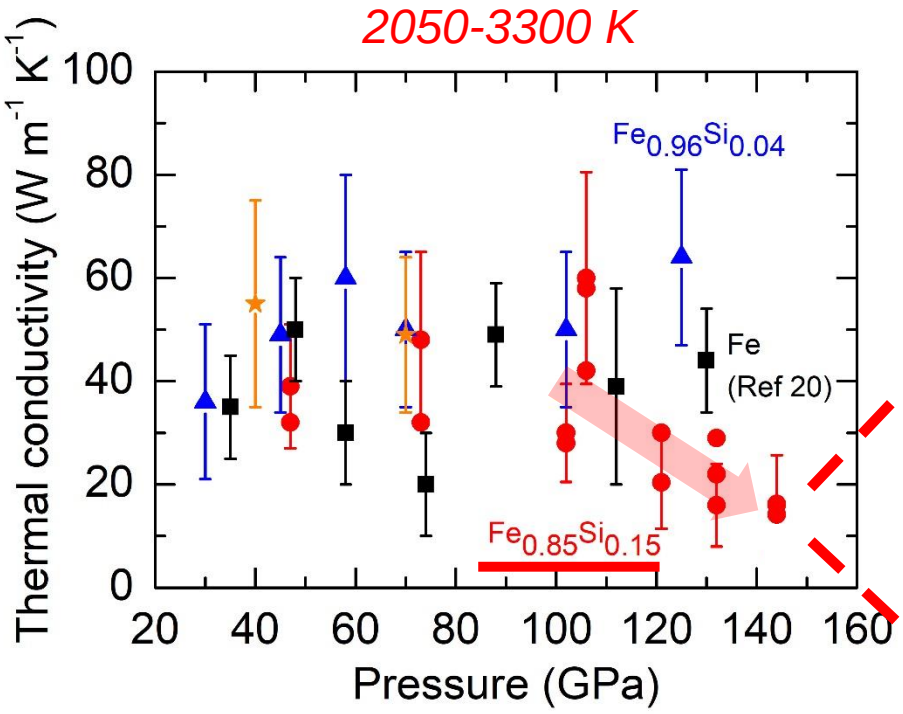


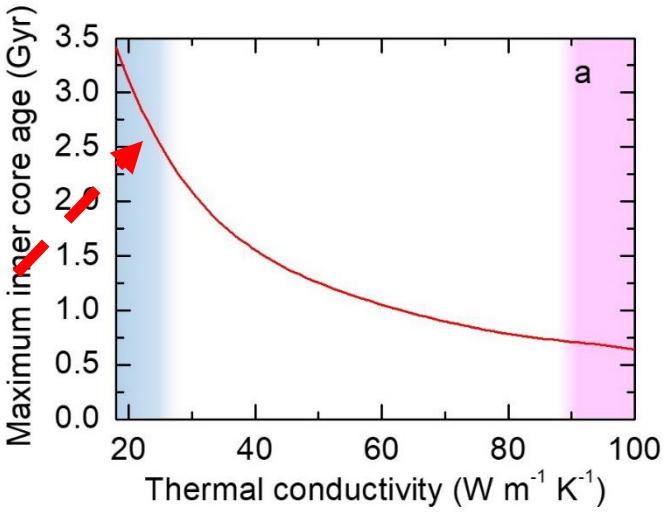
Nature 534, 99 (2016)

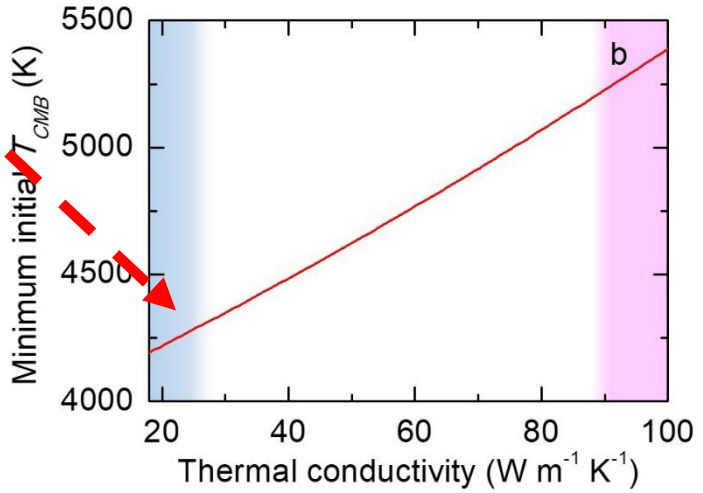
- Extrapolated RT data suggest a **low iron thermal conductivity**: ***inner core would not be as young as sub-Gyr***
- Thermal conductivity of liquid outer core would be even lower!

Wen-Pin Hsieh et al., Nat. Commun. 11, 3332 (2020)

Low core thermal conductivity suggests the inner core could be older than 2.5 Gyr



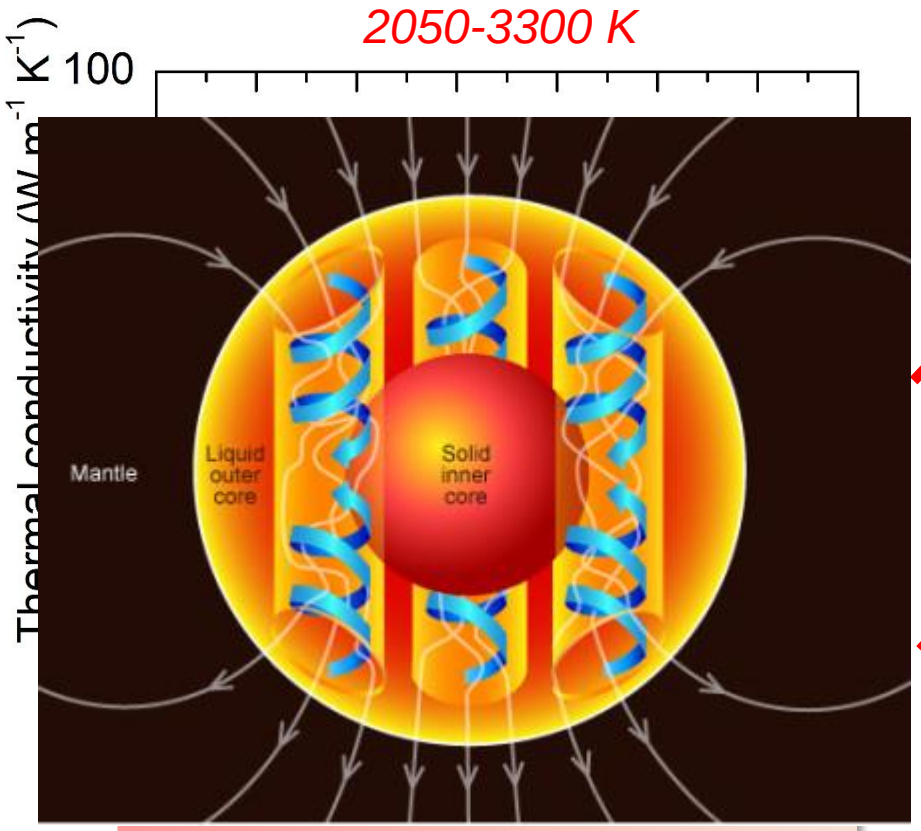




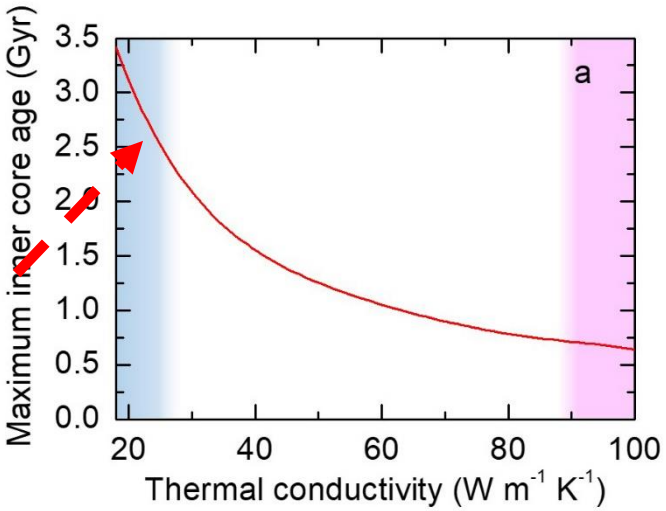
- Inner core could be older than **2.5 billion years old**
- The initial CMB temperature would be around 4500 K

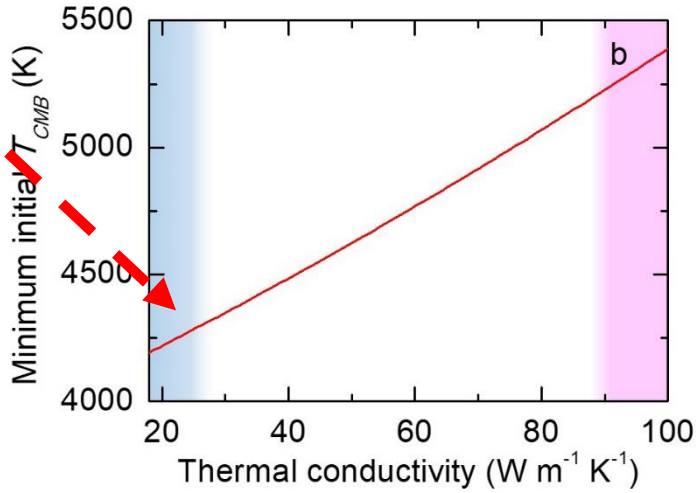
Wen-Pin Hsieh et al., Nat. Commun. 11, 3332 (2020)

Low core thermal conductivity may enable geodynamo to be operated by purely thermal convection



https://en.wikipedia.org/wiki/Dynamo_theory





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Summary

- Combination of **DAC, TDTR, and heating techniques** is powerful to study thermal conductivity of deep Earth minerals at extreme conditions and to tackle very important, unanswered geophysical questions in the deep Earth.
- Need more and closer collaborations with ***theoreticians***, ***geodynamicists***, ***seismologists, and geochemists*** to have a more comprehensive understanding of the core's complex thermo-chemical structure and dynamics.