Radiative conductivity in the earth's lower mantle

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1.Introduction

- Thermal conductivity of lower mantle assembly.
- The importance of temperature and pressure dependence of thermal conductivity.
- Heat conduction mechanism: vibrational transport and radiative conduction.
- Optical absorptivity.
- Concentration and valence state of d-block element.

This paper is to report the new findings in the pressure dependence of optical absorptivity of iron-bearing silicate perovskite, to predict a possible lower thermal conductivity coefficient of lower mantle than that inferred previously.

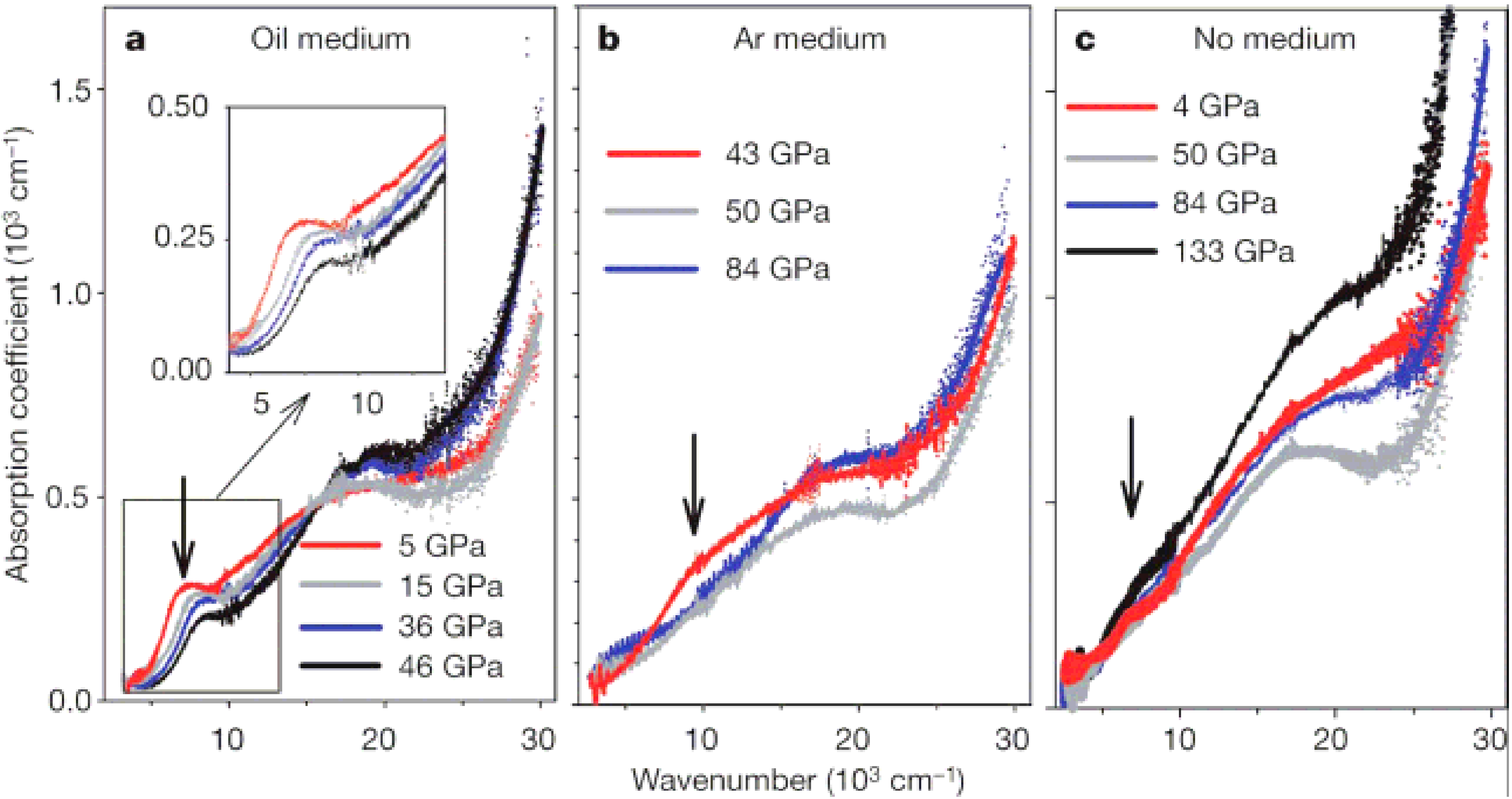
2.Previous measurement on Optical absorptivity

Case of Minerals in previous study	Pressure	Temperature	Reference
Olivine, (Ringwoodite)	20-30GPa	ambient	17,18
Ferropericlase	80GPa	ambient	20,21
Iron-bearing perovskite	ambient	ambient	22,23

3.Experimental Methods

1. DAC pressure apparatus.
   Ambient temperature, up to 133GPa
2. $Mg_{0.9}Fe_{0.1}SiO3$ Perovskite synthesized.
3. Custom infrared microscope
4. all-reflecting relay optics coupled to FTIR
5. near-IR-to-UV spectrograph with
   deuterium/halogen lamps as light source

4.Experimental results and Analysis



Optical absorption spectral of $Mg_{0.9}Fe_{0.1}SiO3$ perovskite with ferric iron 11%
Room temperature.

Pressure dependence of optical absorptivity of $Mg_{0.9}Fe_{0.1}SiO3$ perovskite

Absorption band (cm^{-1})	Measurement parameter	Behavior of Pressure dependence
8000	High-low spin transition of Fe	Blue shift
15000	Fe^{2+}-Fe^{3+} Intervalence charge transfer	Blue shift bellow 50GPa; Red shift above 50GPa
25000	O^{2-}-Fe^{3+} charge transfer	Blue shift at low pressure (46GPa);Red shift at high pressure (above 46GPa)

Comparing to previous prediction

Previous understanding:

1. High-low spin transition considered vas dominant absorption mechanism.
2. Blue shift predicted.
3. Higher radiative conduction at higher pressure predicted.

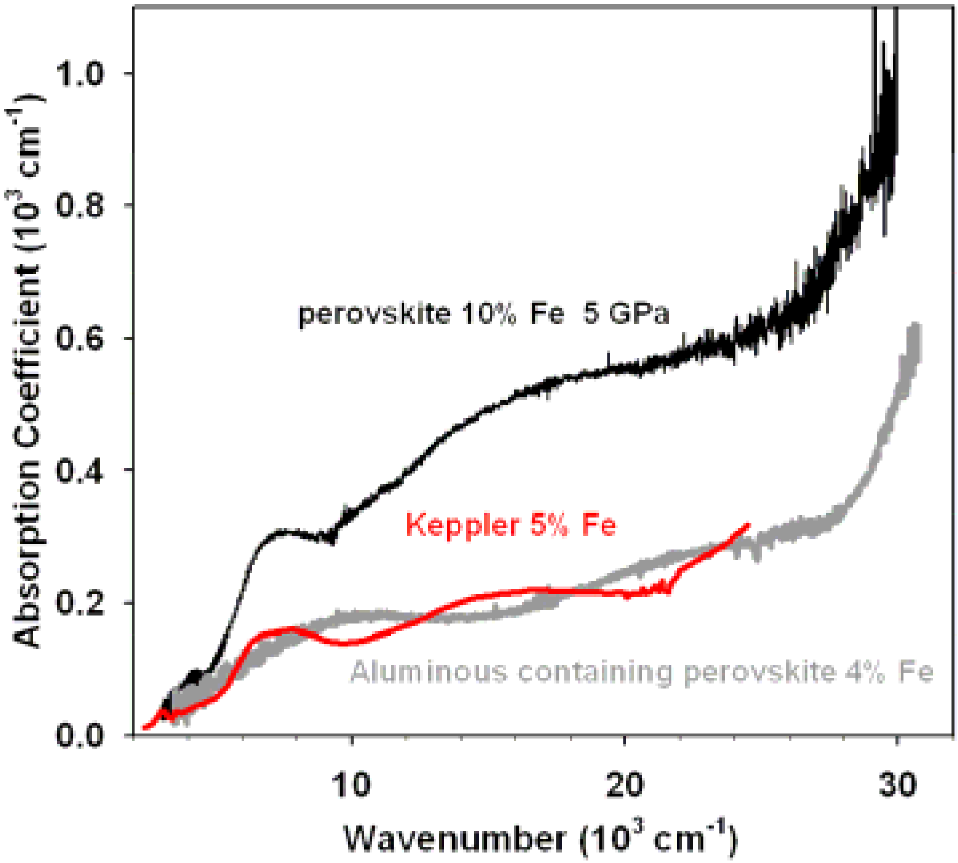
Present finding:

1. Strong pressure dependence. several absorption mechanisms.
2. Red shift above around 50GPa observed.
3. Lower radiative conduction at higher pressure predicted. 2-5 times lower than previous estimation.

Discrepancy: contribution from Ultraviolet-visible absorption tails of O^{2-}—Fe^{3+} charge transfer absorption mechanism, not well considered previously.

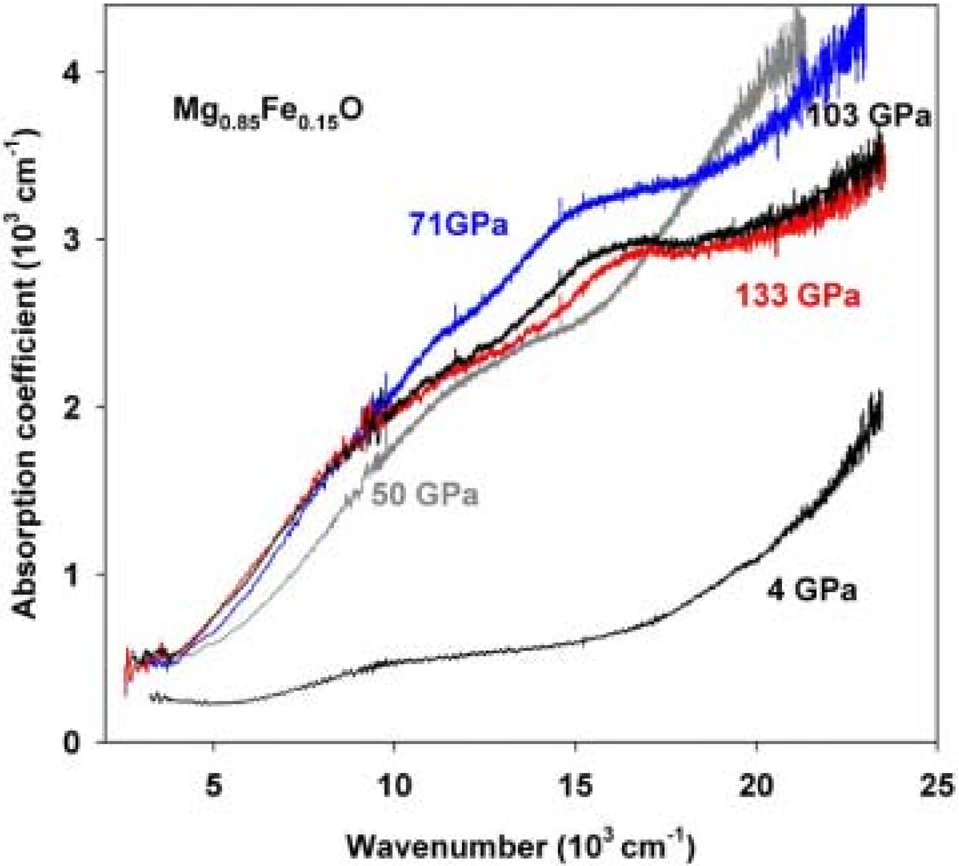
5.Supplimentary experiments for geophysical interpretation

1.strong iron content dependence on 15000cm^{-1} and 25000cm^{-1} band in absorption study of silicate provskite, confirming the iron-related absorption mechanism.



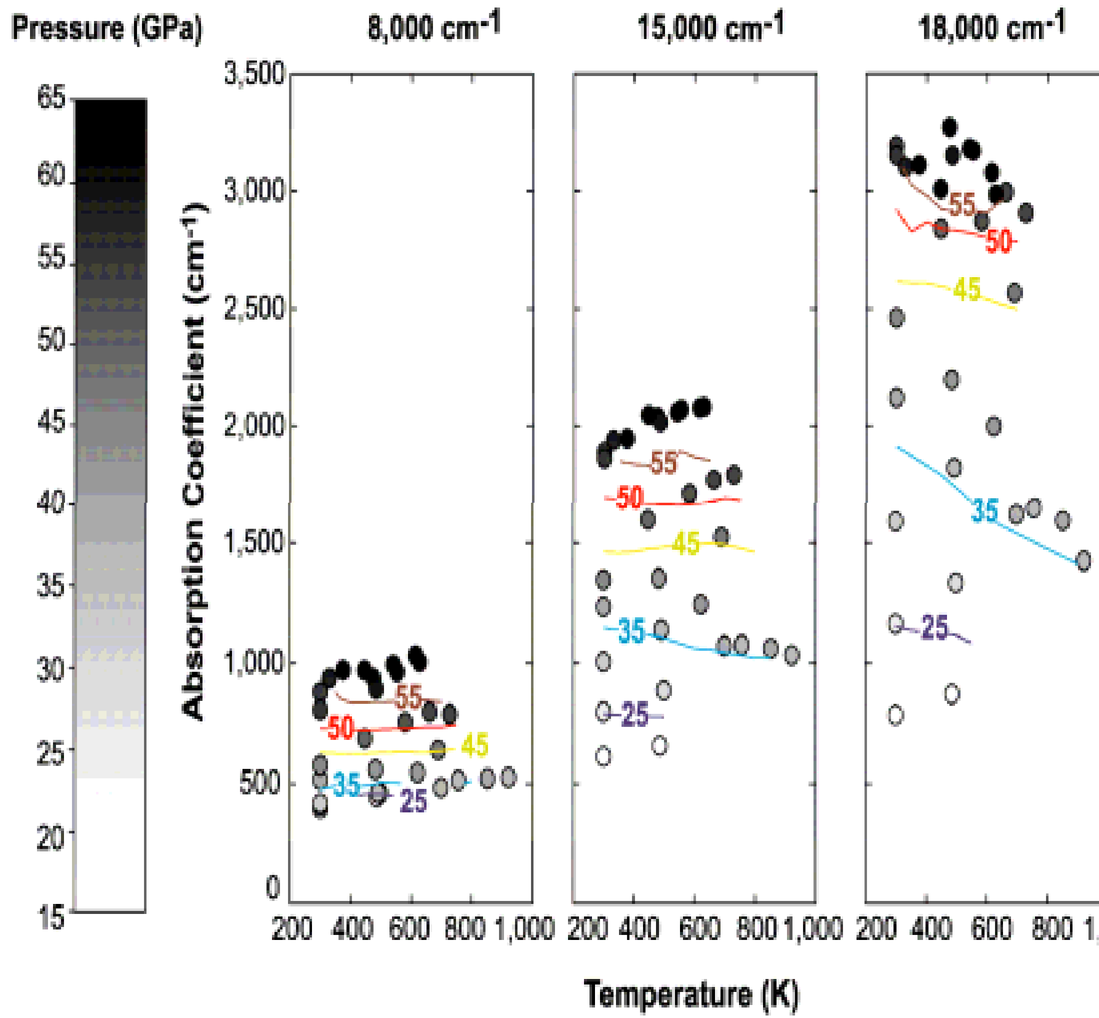
Optical absorption of ferropericlase

2. More obvious pressure dependence of absorptivity of ferropericlase bacause of much high Fe concentration and more O-Fe bonds, also predicting a possible lower thermal conductivity in lower mantle.



Temperature dependence of optical absorptivity

3.Very low temperature
ependence of optical absorptivity
f $Mg_{0.85}Fe_{0.15}O$, expecting a
milar T-dependence expected for
Fe,Mg)SiO3 perovskite because
f the same absorption mechanism.



6. Geophysical interpretation

- Estimated rediative heat conductivity at the top of D'' layer, less than 0.54Wm^{-1}K^{-1}.
- consideration of content of ferric iron and redox state of lower mantle for geotherm model.
- Lower thermal conductivity indicating a less stable and thinner boundary layer.
- Lower thermal conductivity indication a lower plume temperature.
- Reconsider thermal geodynamics model.
- Substantial effort still required on the estimation of Lattice Vibrational thermal conductivity at relevant P-T required.

7.Conclusion

- Iron-bearing silicate perovskite has much high absorptivity in near-IR to visible optical range than that inferred previously.
- The estimated radiative thermal conductivity of mantle perovskite, 2-5 time lower than that inferred previously.
- The radiative component of thermal conductivity in the dominant silicate perovskite is controlled by the amount of ferric iron.
- Stability of boundary layer, plume temperature, geodynamic model should be reconsidered.