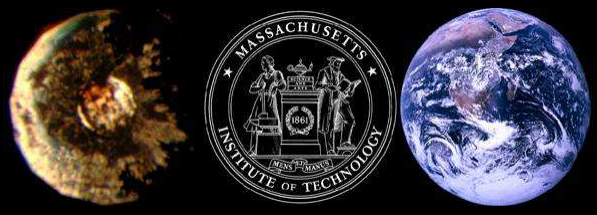
The Core-Mantle Boundary
Mineral Physics Review and Prospect



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Seismic Observations for CMB

Anisotropy
($V_{SH} > V_{SV}$)

Garnero (2000) Annu. Rev. Earth Planet. Sci 28, 509+

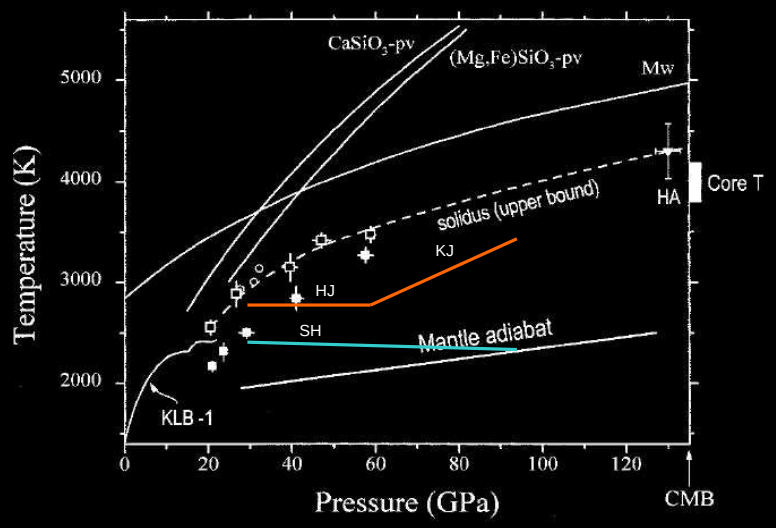
Changes at CMB

	Mantle	Core
Mineralogy	Silicate (Solid)	Iron alloy (Liquid)
Composition	O, Si, Mg, Fe, Ca	Fe, Ni (S, O, Si, H)
$\Delta\rho$ (Mg/m^3)	4.3	
ΔV_P (km/s)	5.7	
ΔV_S (km/s)	-7.3	
ΔT (K)	1000-2000	

Key Issues

- Phase / Composition Change
- Lattice / Shape Preferred Orientation
- Melting, Chemical Reaction

Silicate Melting



Modified from Zerr et al. (1998), HJ = Heinz and Jeanloz (1987, $[Mg,Fe]SiO_3$), KJ = Knittle and Jeanloz (1989, $[Mg,Fe]SiO_3$), SH = Sweeney and Heinz (1993, $[Mg,Fe]SiO_3$), HA = Holland and Ahrens (1997, $[Mg,Fe]_2SiO_4$)

Chemical Reaction

- $(Mg_xFe_{1-x})SiO_3 + 3[(1-x)-y]\ Fe = x\ MgSiO_3 + y\ SiO_2 + [3(1-x)-2y]\ FeSi + [(1-x)-y]\ FeO$

  (x=0.9, y=0.05 at 70 GPa, Knittle and Jeanloz, 1989)

- $0.5x\ Al_2O_3 + [1+1.5x]\ Fe = FeAl_x + 1.5x\ FeO$

  (x = 0.02 - 0.25 above 65 GPa and 2000 K, Dubrovinsky et al., 2001)

- $x\ SiO_2 + [1+2x]\ Fe = 2x\ FeO + FeSi_x$

  (x=0 above 80 GPa, Dubrovinsky et al., 2003)

- FeMg – Alloy (Dubrovinsky et al., 2004)

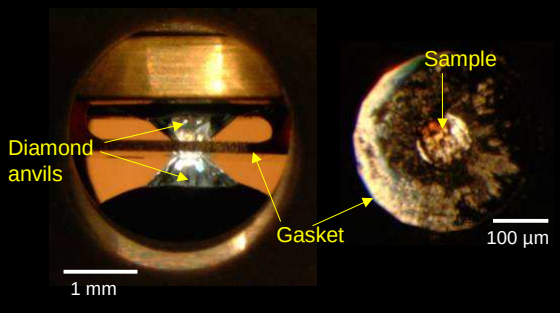
Mineral Texture at CMB

- Whereas LPO in mantle silicates (Mg-pv, Mw, Stv) does not provide satisfactory explanation for the observed anisotropy, SPO is the more likely mechanism in the form of horizontally oriented disk-shaped inclusions (Kendall and Silver, 1998).

- Combined with mineral physics experiments on (Mg,Fe)O, predict $V_{SH} > V_{SV}$ anisotropy (consistent with seismological results for paleoslab regions) (McNamara et al., 2002).

Measurements at CMB Conditions

P = 120 – 140 GPa, T = 2500 – 4000 K



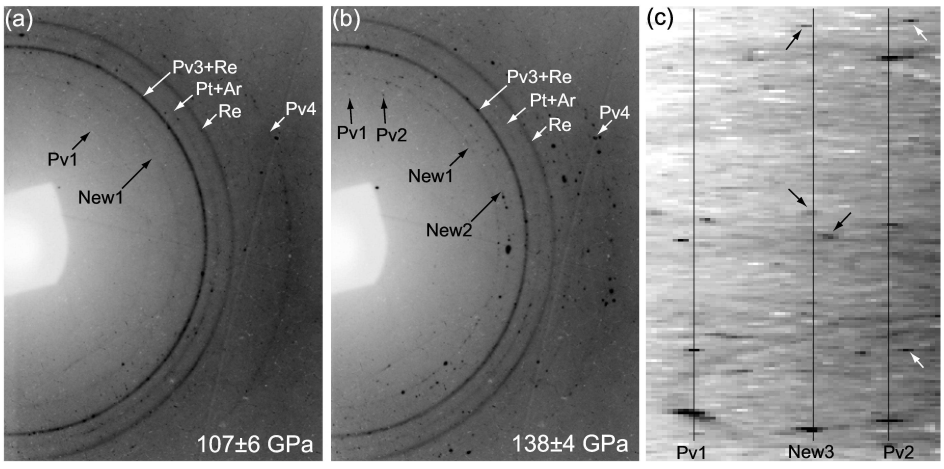
Post-Perovskite Phase Transition

Experiment

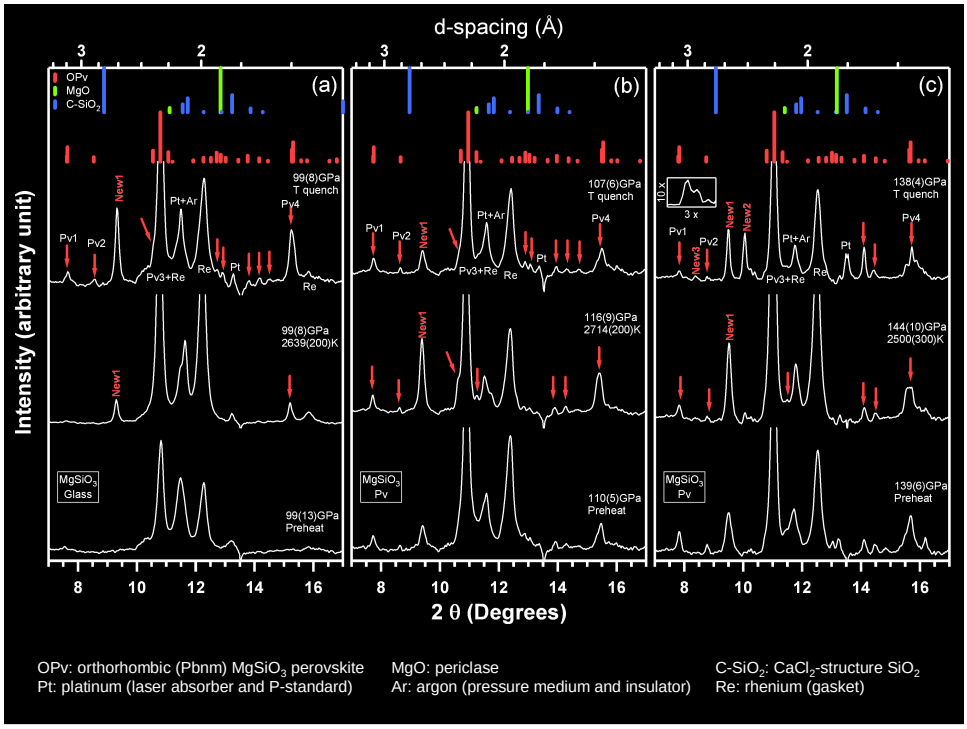
- Murakami M., K. Hirose, K. Kawamura, and N. Sata and Y. Ohishi, Science 304, 855-858 (2004)
- S.-H. Shim, T. S. Duffy, R. Jeanloz, and G. Shen, GRL 31, L10603 (2004)
- A. R. Oganov and S. Ono, Nature 430, 445-448 (2004)

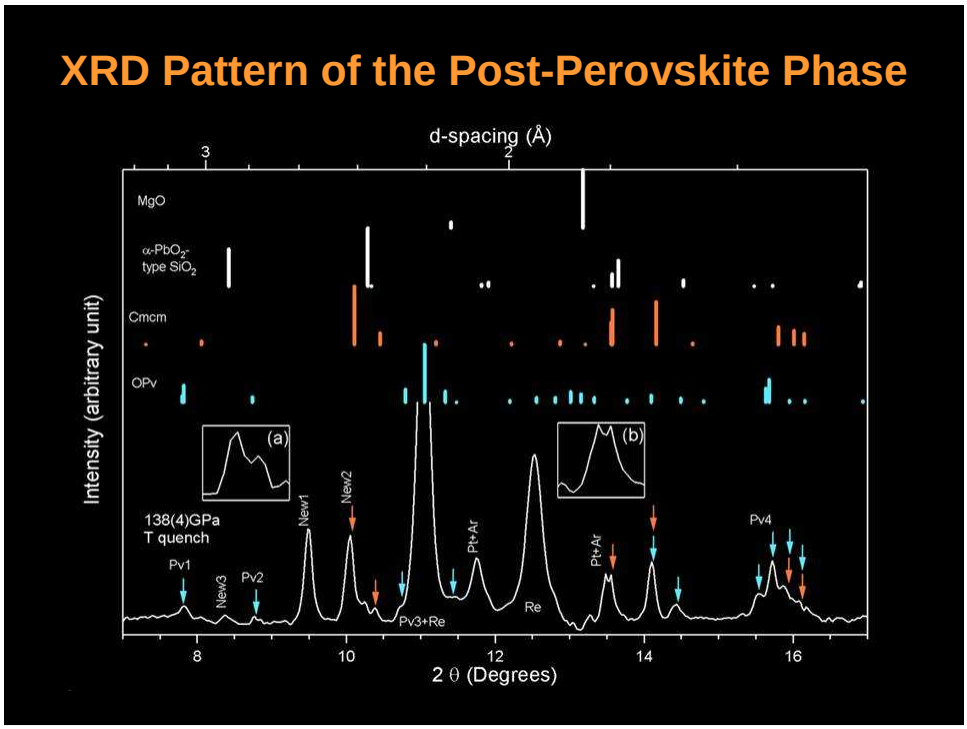
Theory

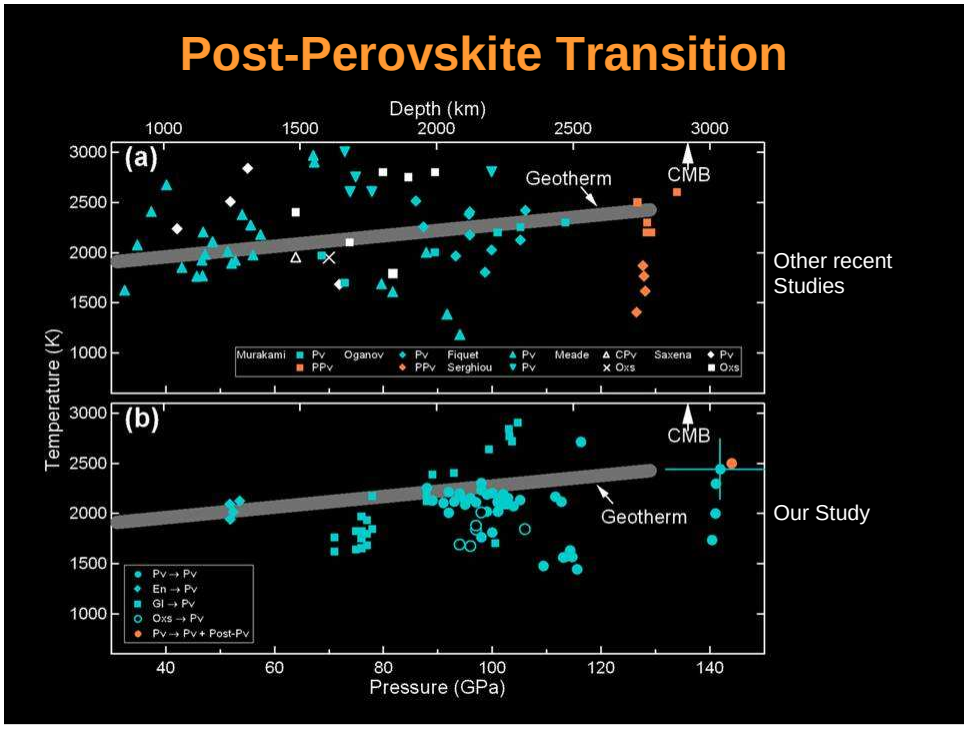
- T. Iitaka, K. Hirose, K. Kawamura, and M. Murakami, Nature 430, 442-445 (2004)
- A. R. Oganov and S. Ono, Nature 430, 445-448 (2004)
- T. Tsuchiya, J. Tsuchiya, K. Umemoto, and R. M. Wentzcovich, EPSL (in the press)
- T. Tsuchiya, J. Tsuchiya, K. Umemoto, and R. M. Wentzcovich, GRL 31, L14603 (2004)

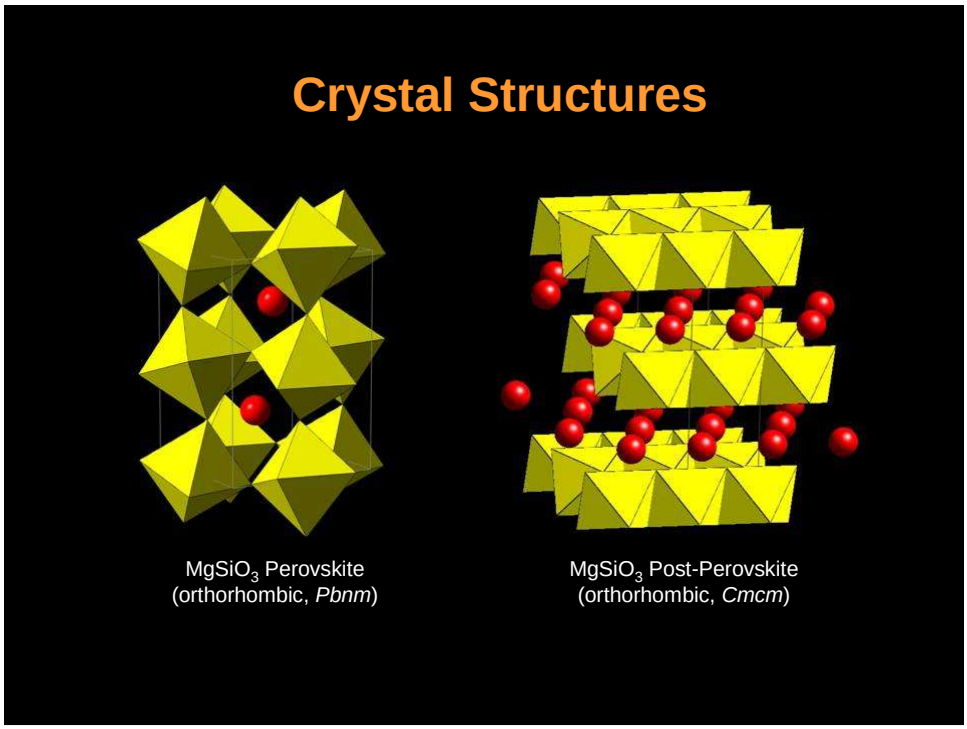


Pv: $MgSiO_3$ perovskite, Re: rhenium gasket, Pt: platinum laser absorber, Ar: argon pressure medium


d-spacing (Å)
Intensity (arbitrary unit)
2 θ (Degrees)
OPv
MgO
C-SiO2
(a)
(b)
(c)
Pv1
Pv2
New1
New2
New3
Pt+Ar
Pv4
Pv3+Re
Re
Pt
99(8)GPa T quench
107(6)GPa T quench
138(4)GPa T quench
99(8)GPa 2639(200)K
116(9)GPa 2714(200)K
144(10)GPa 2500(300)K
MgSiO3 Glass
MgSiO3 Pv
99(13)GPa Preheat
110(5)GPa Preheat
139(6)GPa Preheat
OPv: orthorhombic (Pbnm) MgSiO3 perovskite
Pt: platinum (laser absorber and P-standard)
MgO: periclase
Ar: argon (pressure medium and insulator)
C-SiO2: CaCl2-structure SiO2
Re: rhenium (gasket)


XRD Pattern of the Post-Perovskite Phase
d-spacing (Å)
Intensity (arbitrary unit)
2 θ (Degrees)
MgO
α-PbO2-type SiO2
Cmcm
OPv
(a)
(b)
138(4)GPa T quench
Pv1
New3
Pv2
New1
New2
Pv3+Re
Pt+Ar
Re
Pv4


Post-Perovskite Transition
Depth (km)
1000
1500
2000
2500
3000
(a)
Geotherm
CMB
Other recent Studies
Murakami Pv PPv
Oganov Pv PPv
Fiquet Serghiou
Meade Pv Pv
CPv Oxs
Saxena Pv Oxs
Temperature (K)
(b)
CMB
Geotherm
Our Study
Pv → Pv
En → Pv
Gl → Pv
Oxs → Pv
Pv → Pv + Post-Pv
40
60
80
100
120
140
Pressure (GPa)


Crystal Structures
MgSiO3 Perovskite
(orthorhombic, Pbnm)
MgSiO3 Post-Perovskite
(orthorhombic, Cmcm)

What the Post-Pv Phase Can Explain

- S-wave sensitive seismic discontinuity at 200-km above the D”
- Positive slope of the discontinuity
- Seismic anisotropy at D”

Future Studies

- Existence of the post-perovskite phase in $(Mg,Fe,Al,Si)O_3$.
- P-T slope of the post-perovskite transition (relation with perovskite phase).
- Melting, element partitioning, elasticity, equation of state, and chemical reaction of the post-perovskite phase at high P-T.