"Does partial melting occur today in the D''-layer ?

What would happen to the liquids ?"

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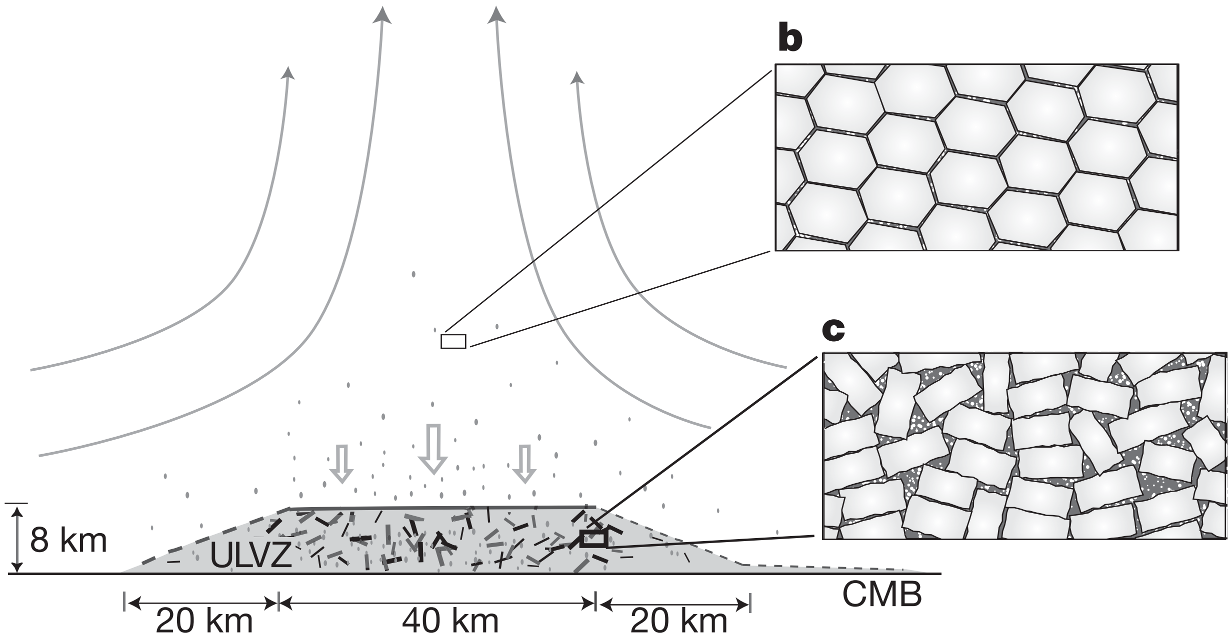
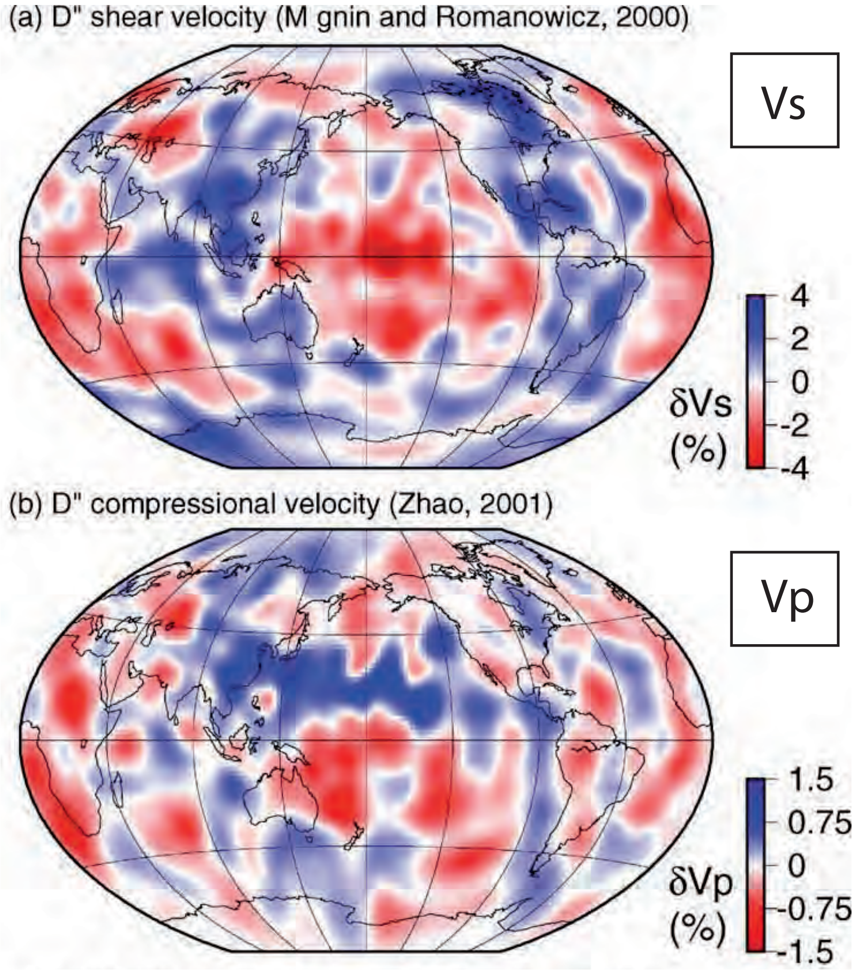


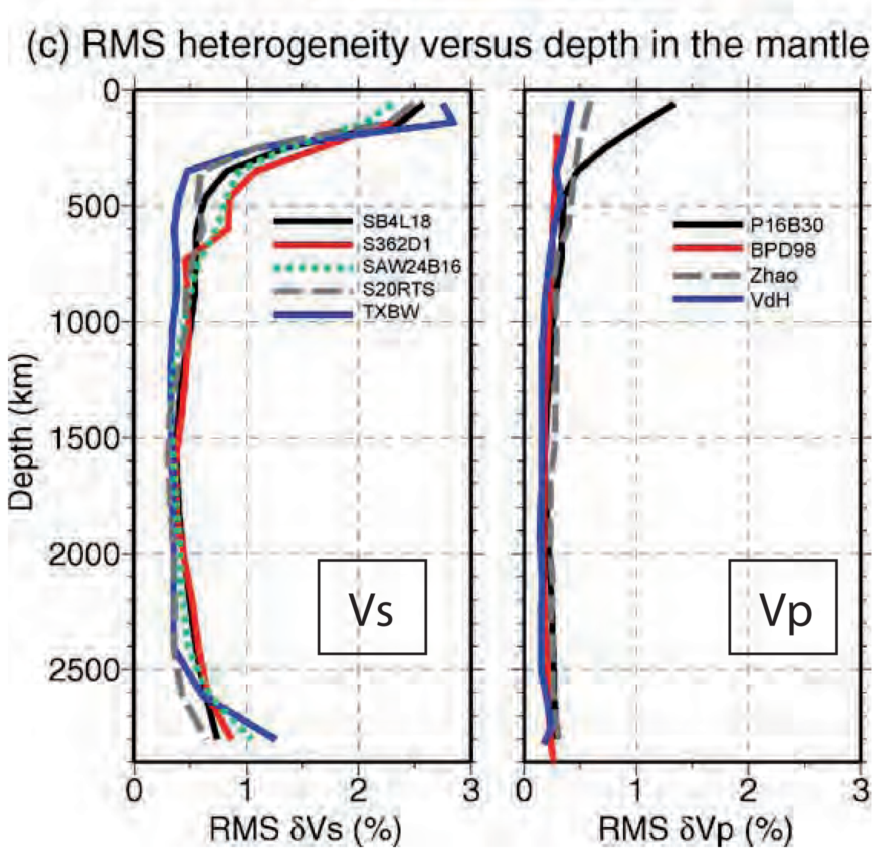
Rost et al., 2005

Seismic anomalies in the D" layer

Ultra-low Velocity Zones

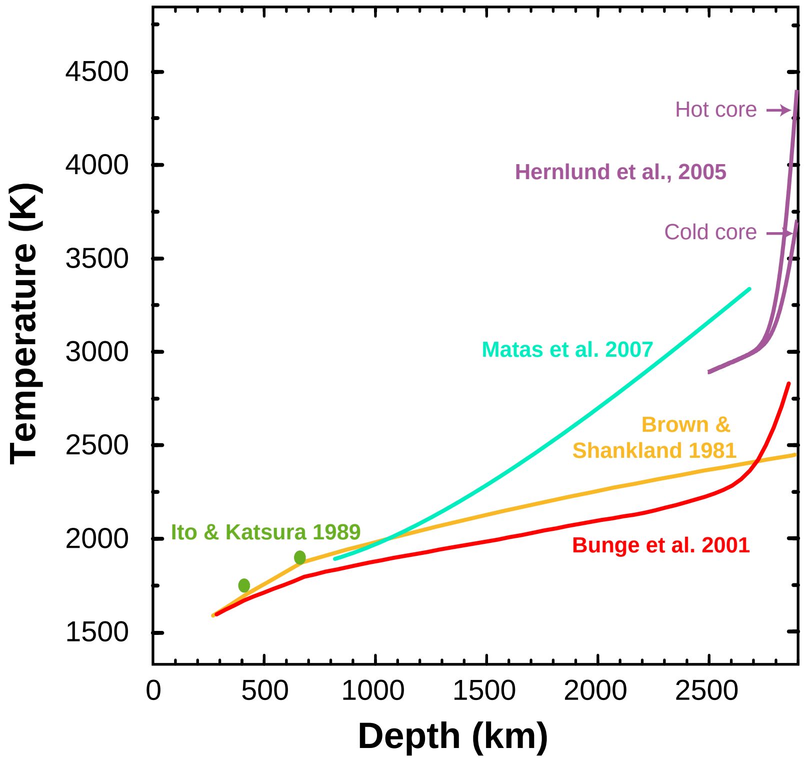
=> Mantle partial melting ?

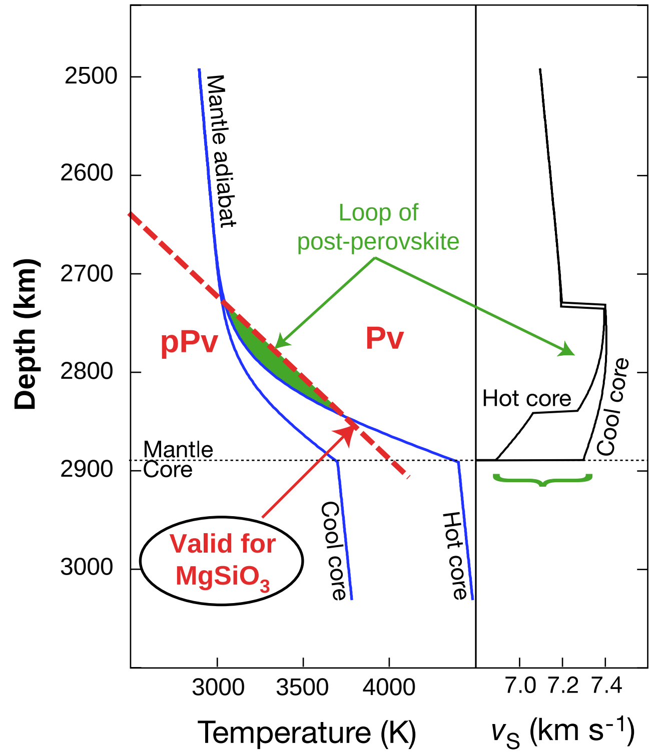




Lay et al., 2004

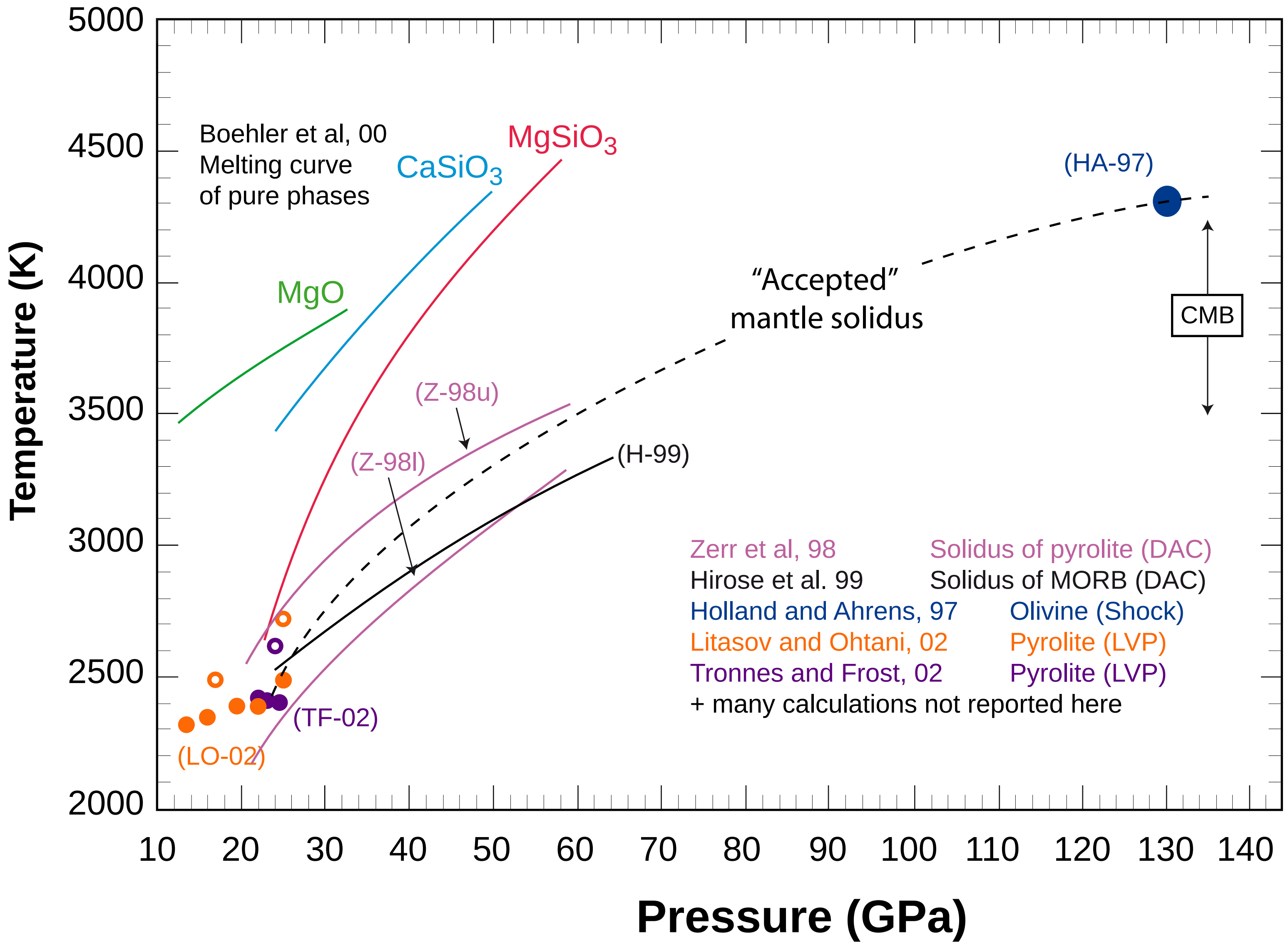
Temperature profile in the deep mantle



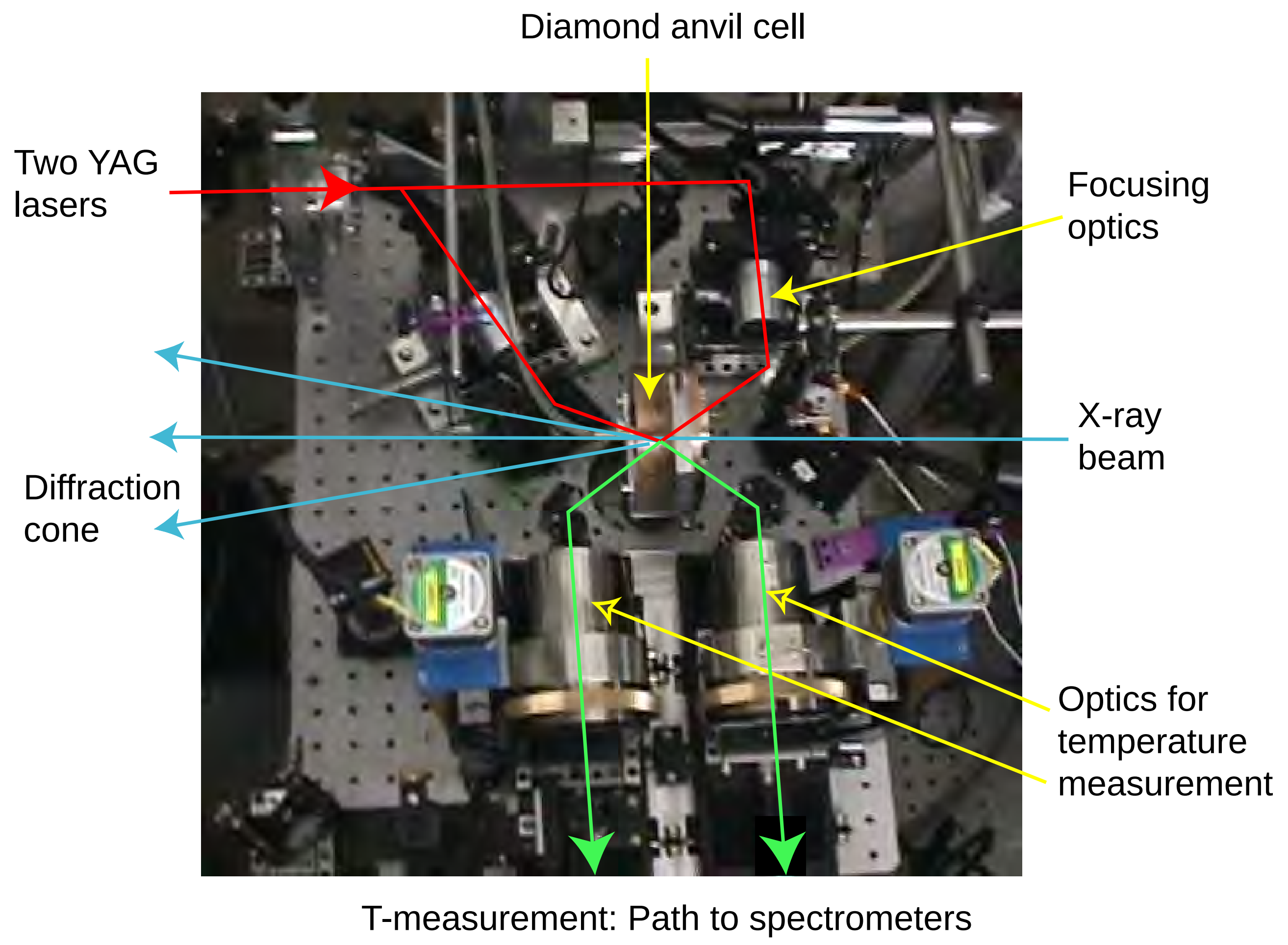


Hernlund et al., 2005

Previous melting experiments of the Earth deep mantle



New melting curve determination using X-ray diffraction



Sample: Glass of chondritic mantle composition

Pressure-medium: KCl or NaCl

Temperature measurements: Black body emission

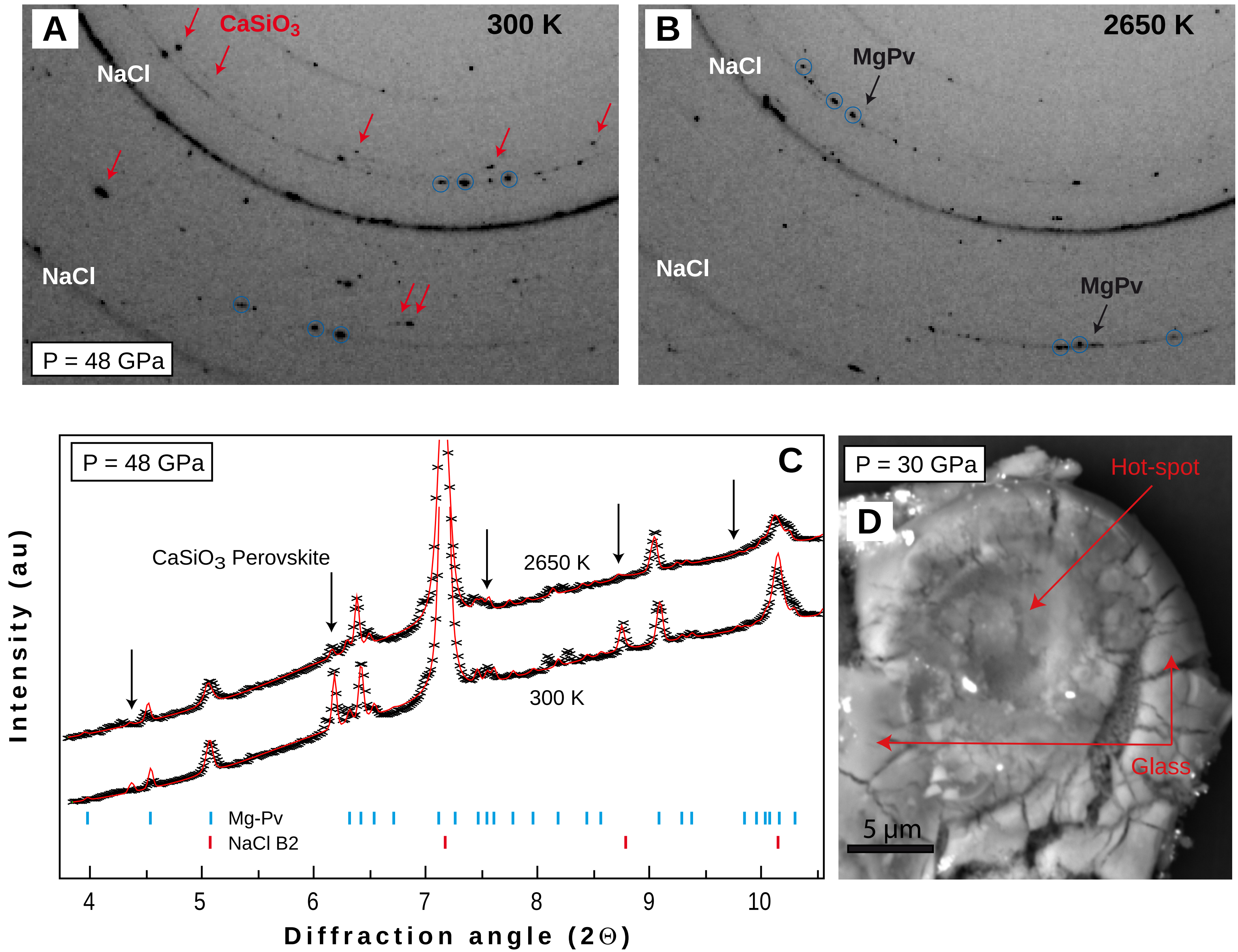
Pressure measurements:
- @ room T: NaCl or KCl or Re
- @ high T: Correction for effect of Pth

Criterion for sample melting (solidus and liquidus):

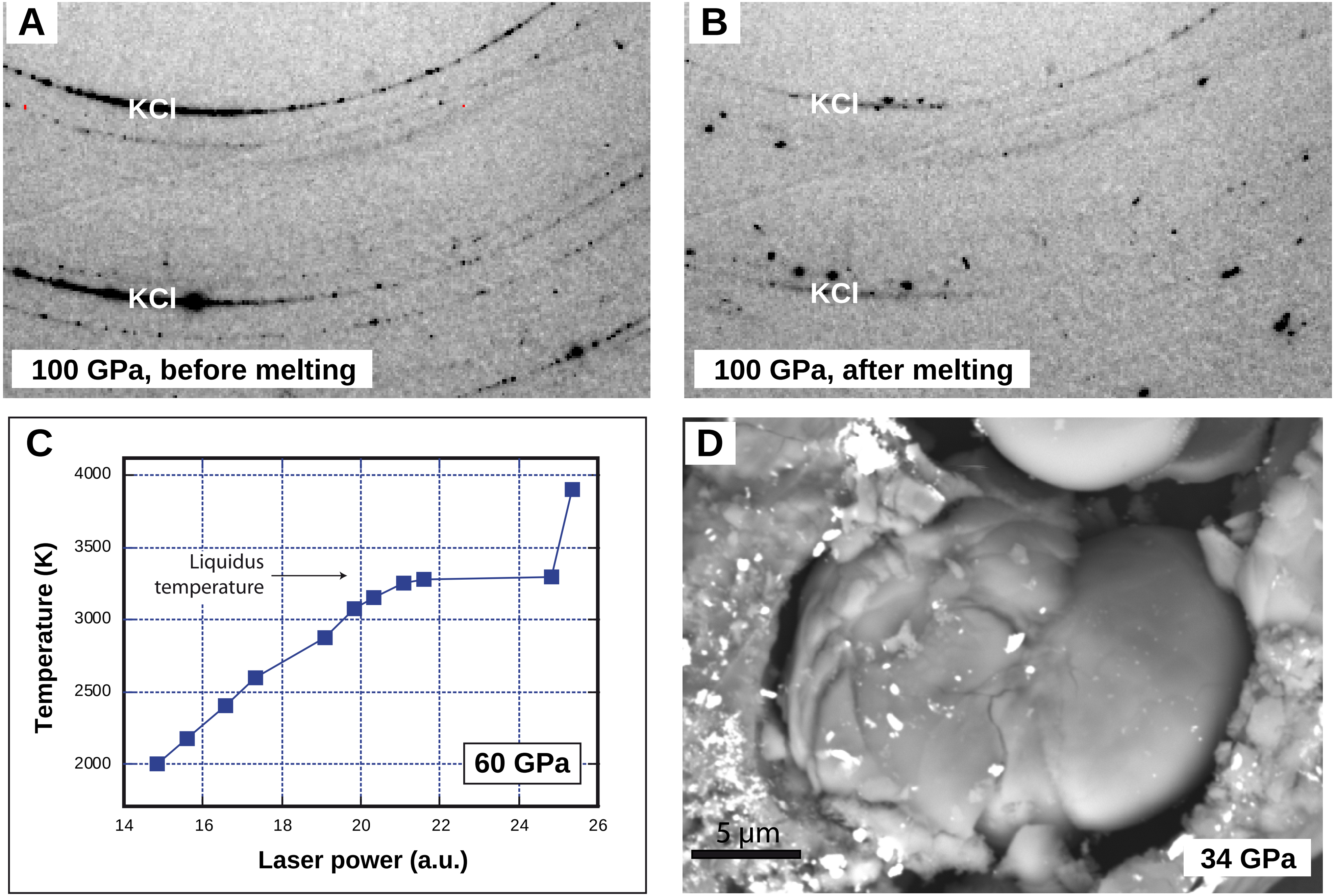
VISUAL
- Change of the laser absorbance
- Discontinuity in <sample T vs laser power>
- Change of sample shape

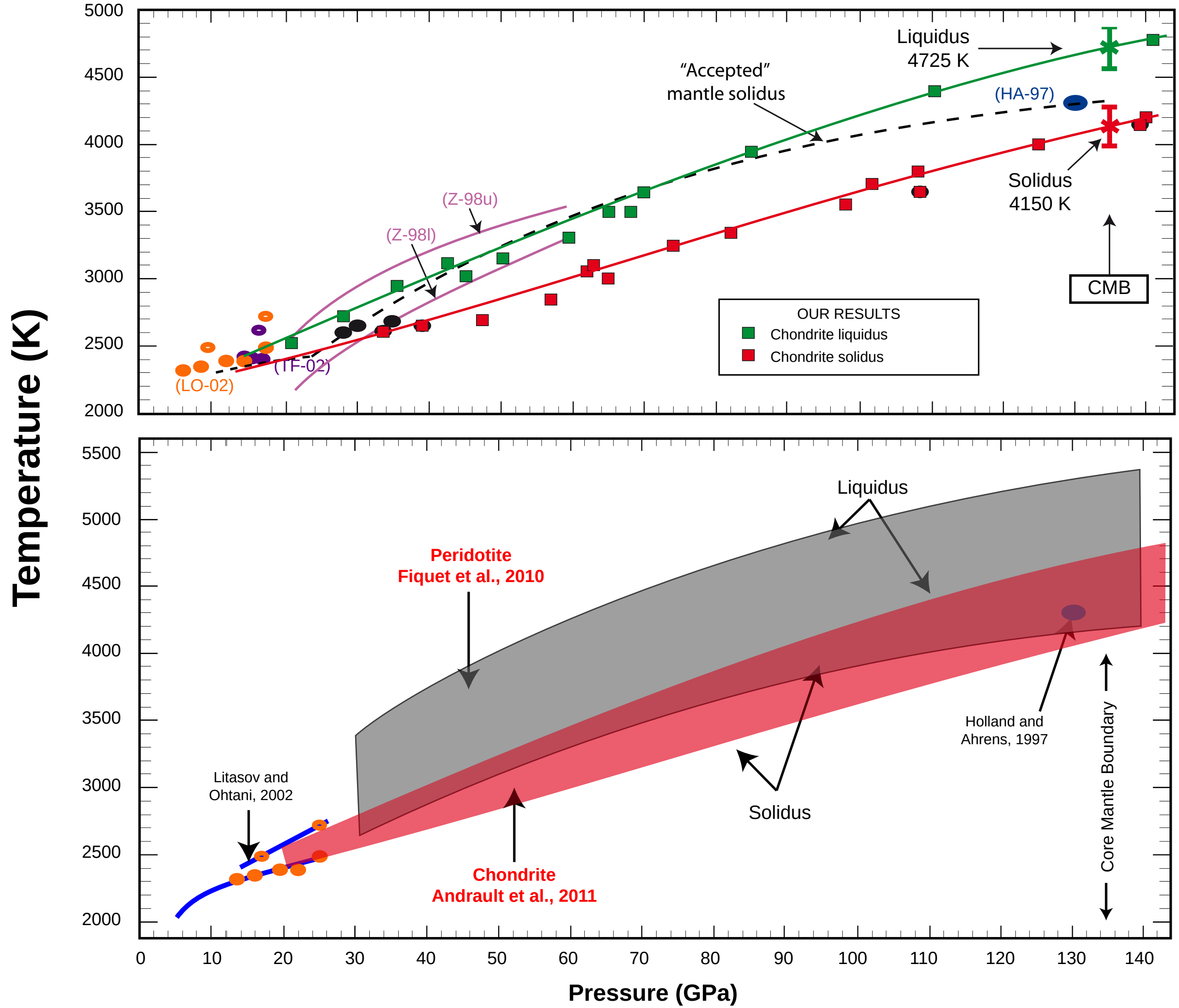
X-ray DIFFRACTION
- Peaks disappearance at high T
- Peaks reappearance on T-quenching
- Appearance after quenching temperature of new grains of mineral phases
- Appearance of a broad band of diffuse scattering

Solidus evidences



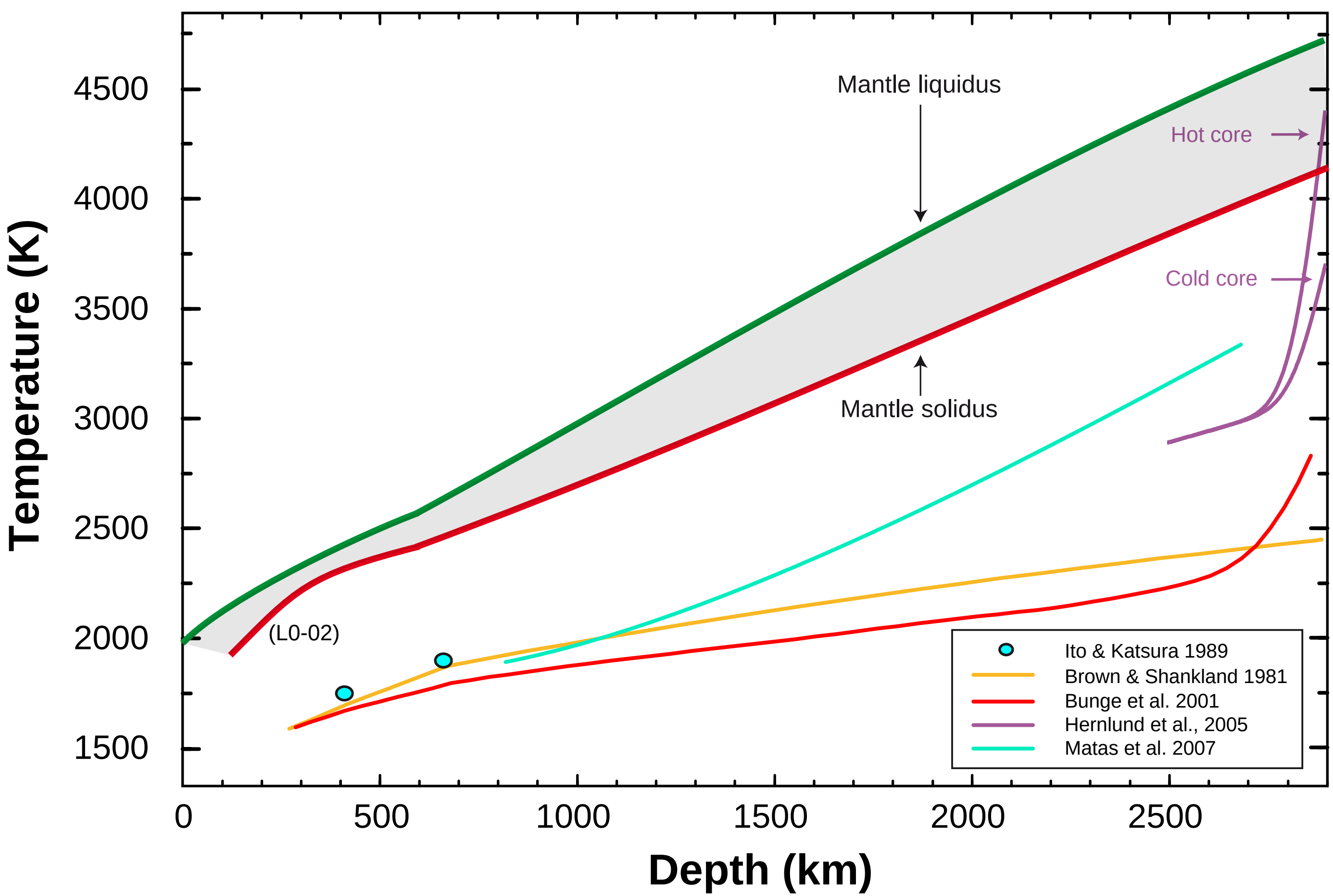
Liquidus evidences



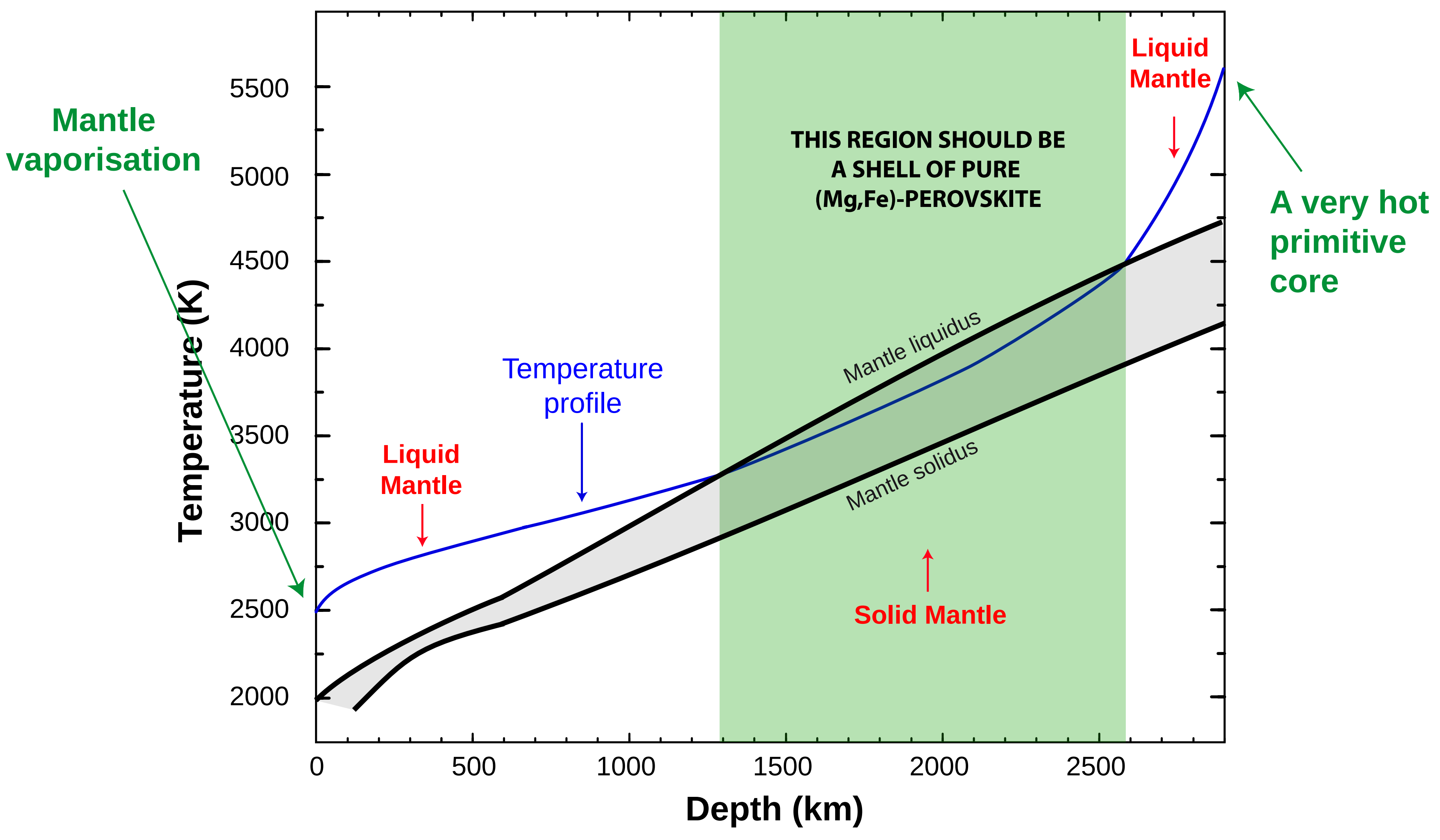


Temperature (K)
Pressure (GPa)
Liquidus
4725 K
"Accepted"
mantle solidus
(HA-97)
Solidus
4150 K
CMB
(Z-98u)
(Z-98l)
(TF-02)
(LO-02)
OUR RESULTS
Chondrite liquidus
Chondrite solidus
Liquidus
Peridotite
Fiquet et al., 2010
Holland and
Ahrens, 1997
Core Mantle Boundary
Solidus
Litasov and
Ohtani, 2002
Chondrite
Andrault et al., 2011

Comparison with some temperature profiles



A temperature profile compatible with a basal magma ocean ?



CONCLUSIONS

Does partial melting occurs today in the D”-layer ?

Not if “classical” lower mantle temperature profiles are true.

Could be possible if

- the core is extremely hot; more than 4150 K at the CMB
- fusible elements are concentrated in this mantle region

What would happen to the liquids ?

Major parameters controllng the relative buoyancy (floatability) between melt and mantle:

Density = Masse / Volume

Volume of melting: ΔV of a few %

ΔV decreasing with increasing pressure

ΔV becomes virtually zero at infinite pressure

Fe-partitioning between solid mantle and melt

Fe is heavier than Mg

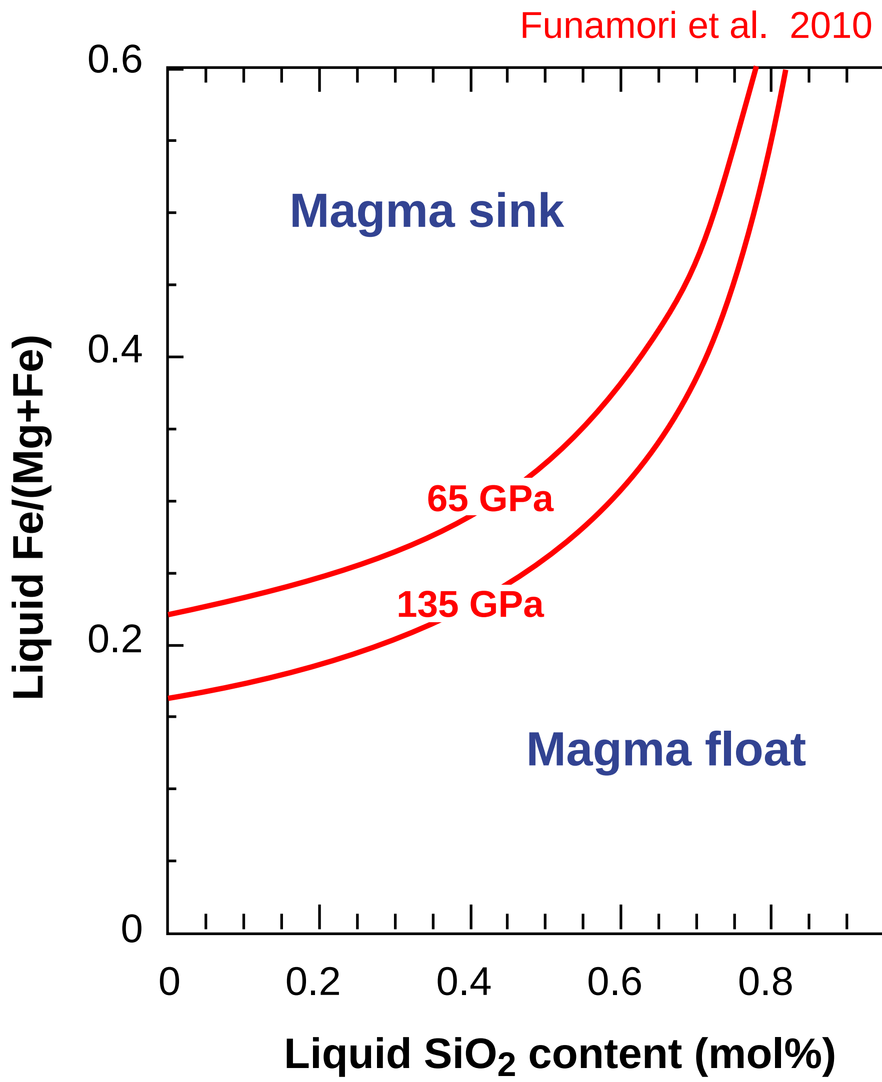
Fe is bigger than Mg in high-spin state

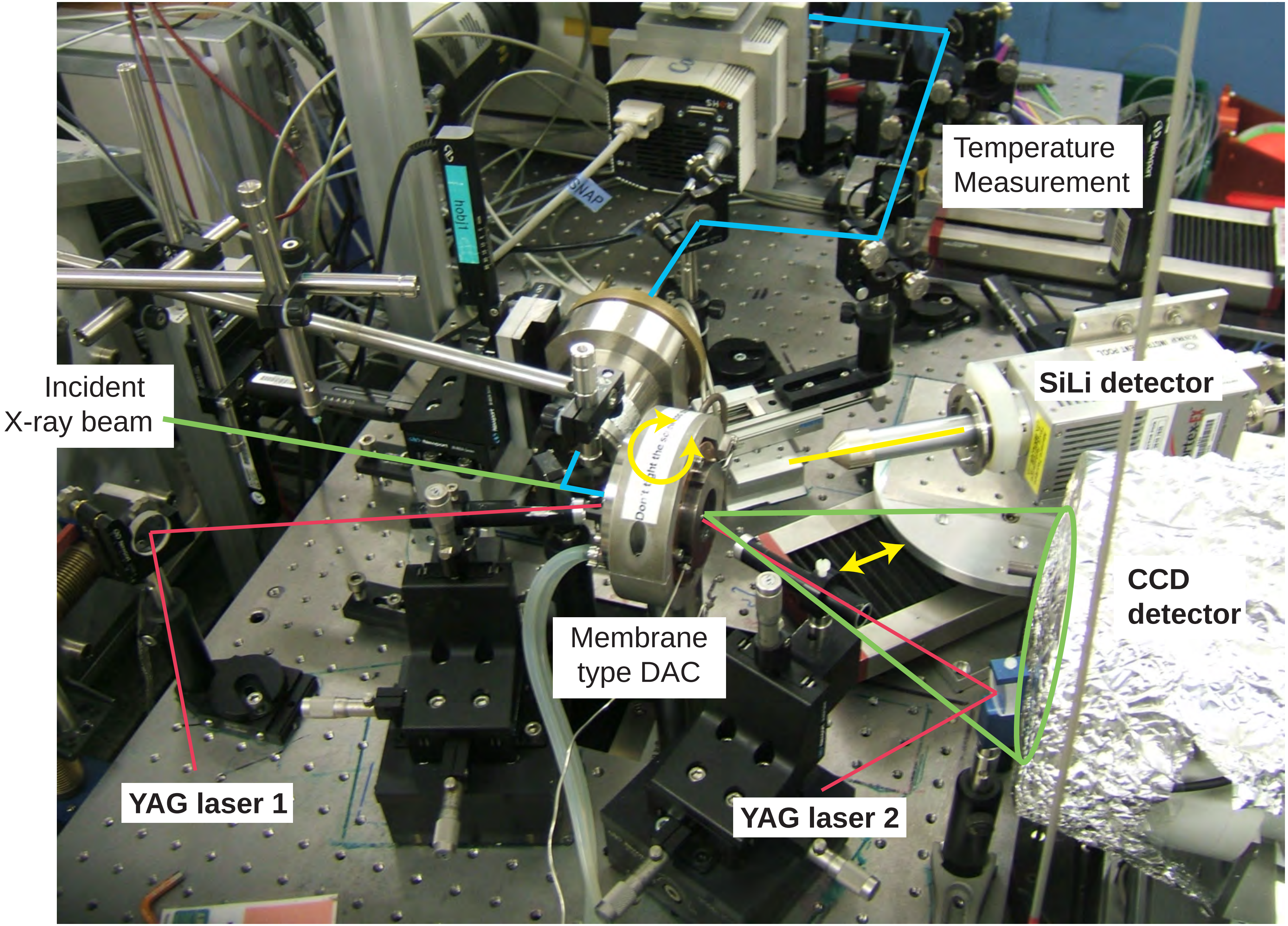
Fe is of same size than Mg in low-spin state

MgO/SiO2 ratio in the liquid

SiO2 is less dense than (Mg,Fe)SiO3

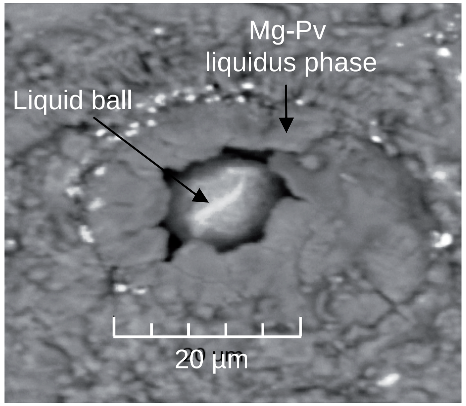
SiO2 is very incompressible




Temperature
Measurement
SiLi detector
Incident
X-ray beam
CCD
detector
Membrane
type DAC
YAG laser 1
YAG laser 2

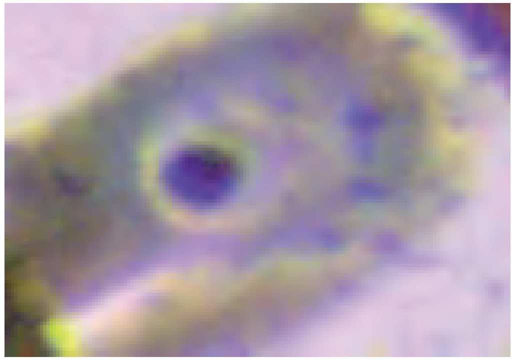
Melting for ~20 seconds

P=78 GPa



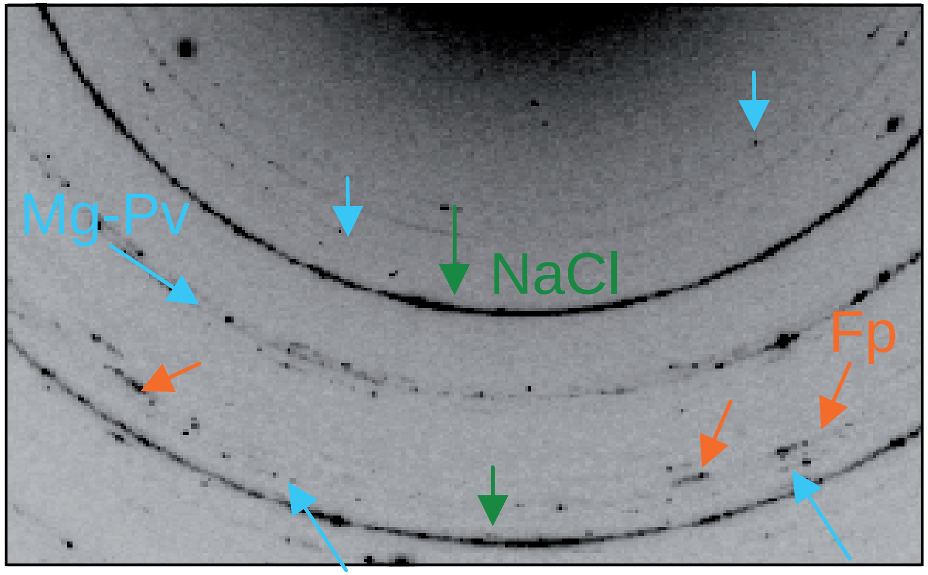
Melting for ~2 seconds

P=58 GPa



X-ray diffraction results

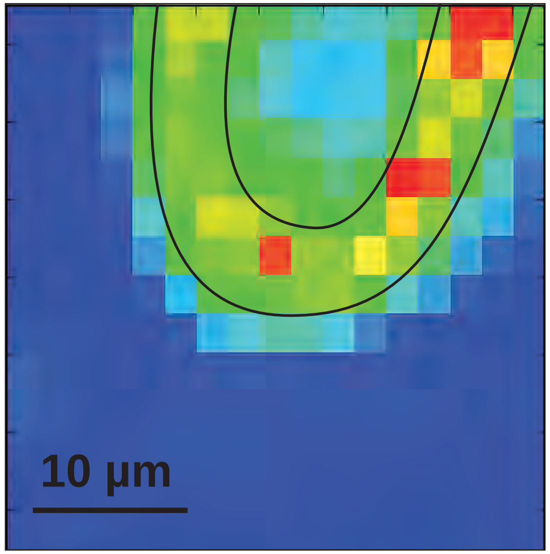
Typical X-ray diffraction image



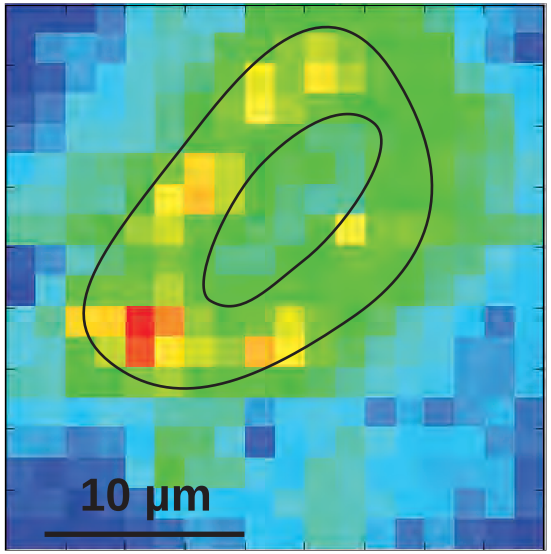
Recorded at each sample position

=> provide maps of Al-bearing (Mg,Fe)SiO3 perovskite content

55 GPa

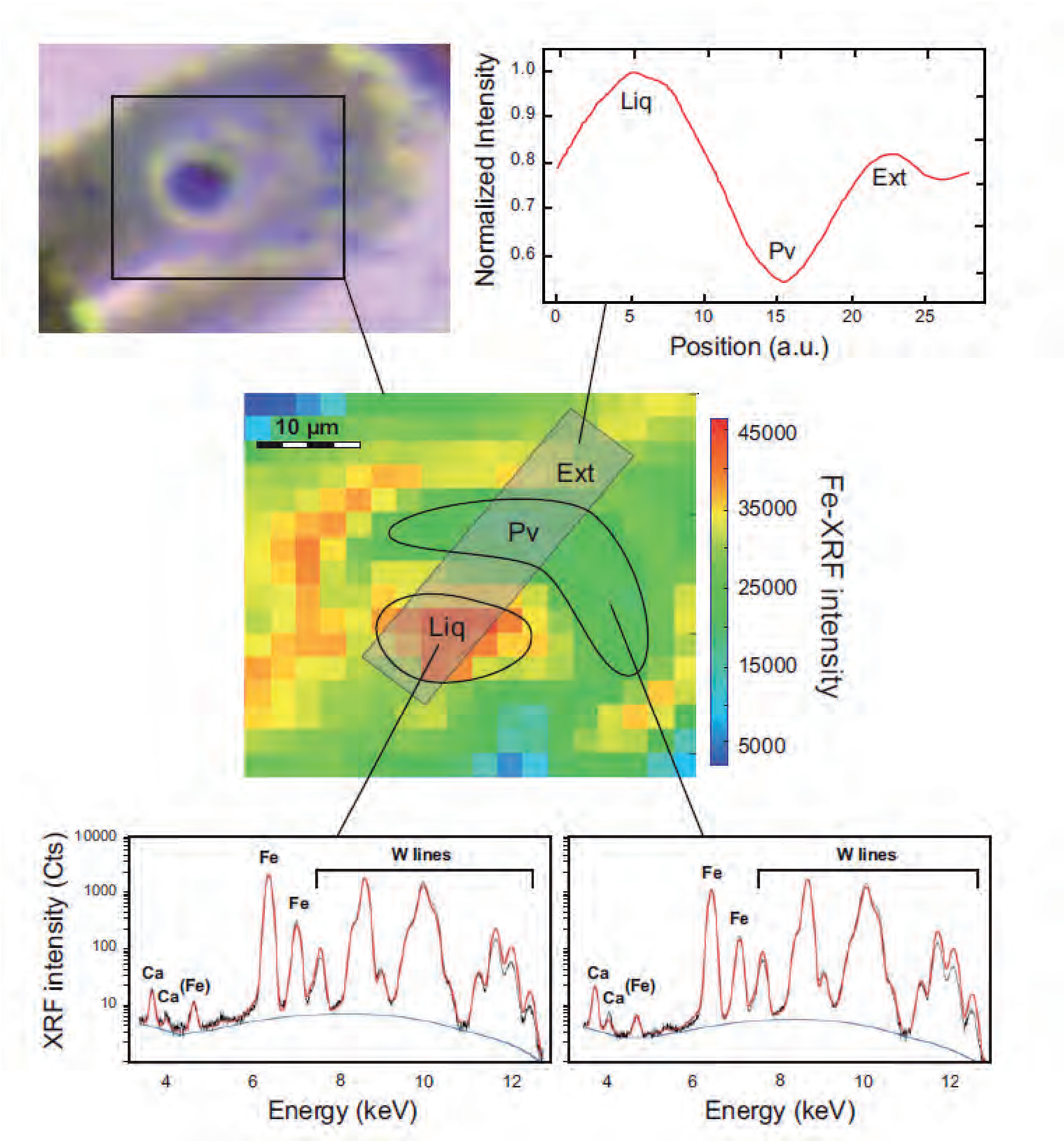


113 GPa

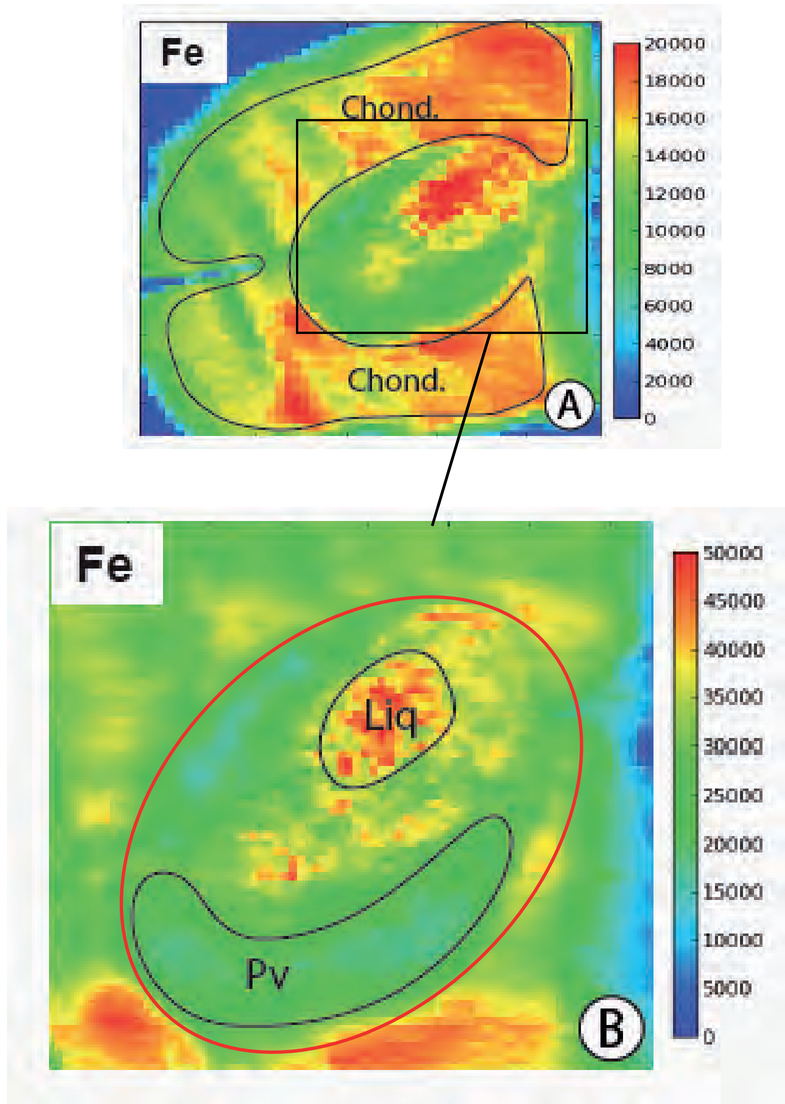


~2 µm spatial resolution mapping at ID27
Simultaneous with X-ray diffraction

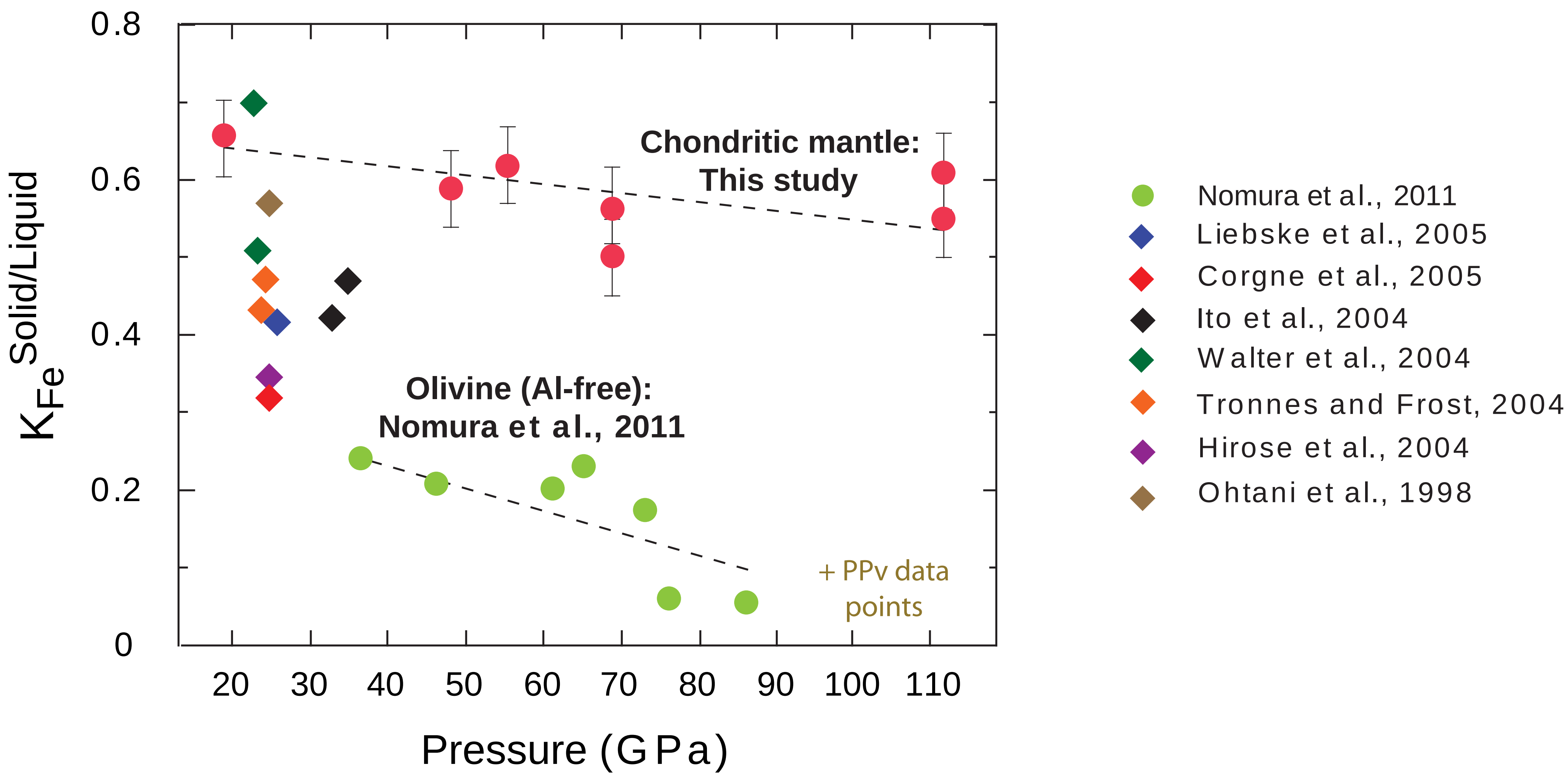
~0.5 µm spatial resolution mapping at ID21
X-ray energy adapted to Fe XRF signal



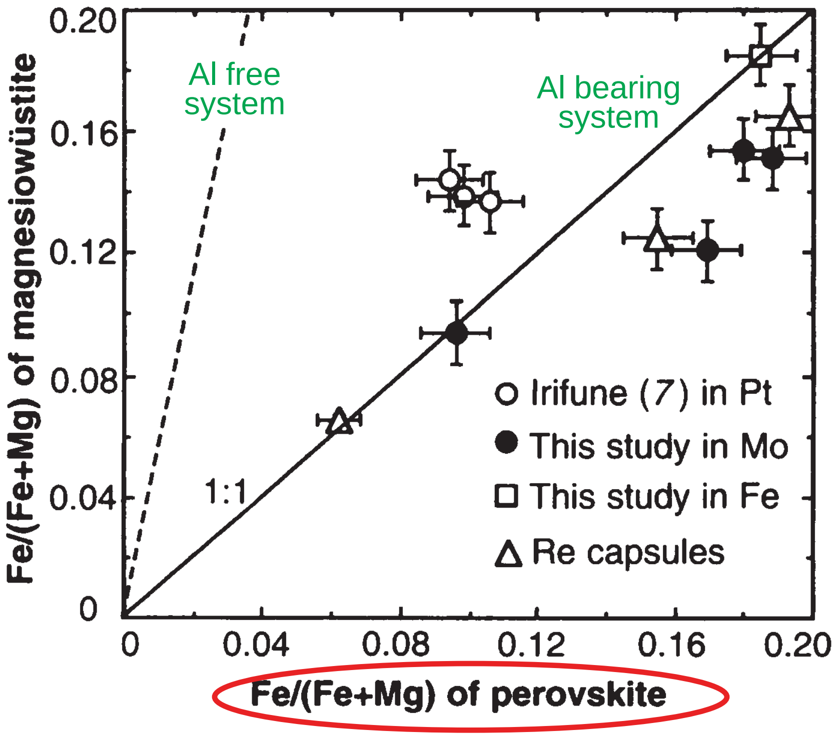
58 GPa



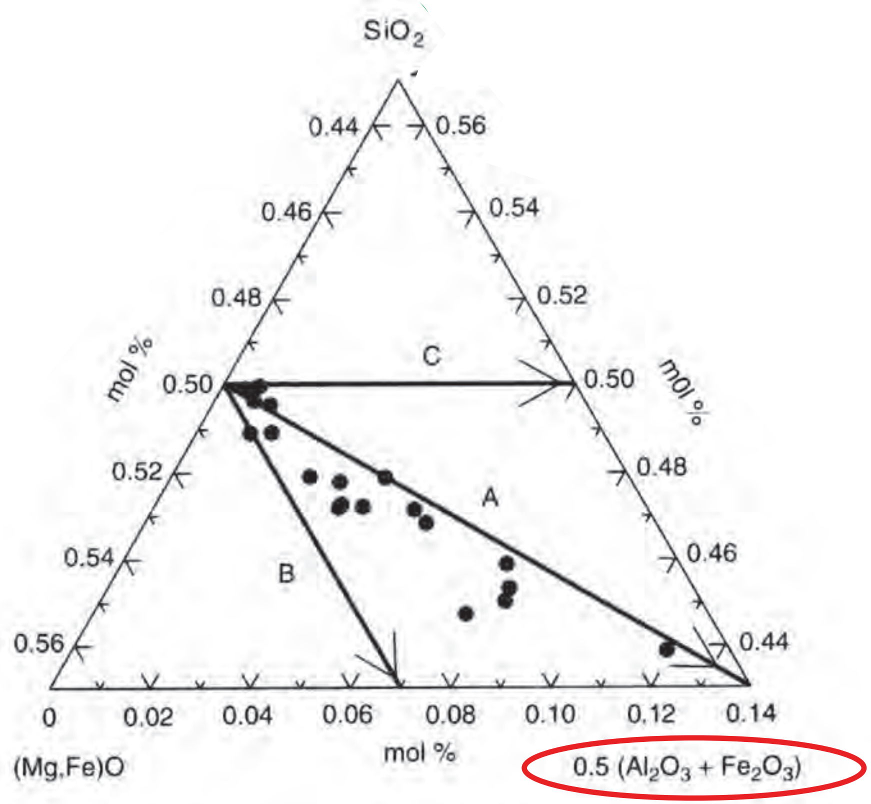
105 GPa


0.8
0.6
0.4
0.2
0
$K_{Fe}^{Solid/Liquid}$
Chondritic mantle:
This study
Olivine (Al-free):
Nomura et al., 2011
+ PPv data
points
20
30
40
50
60
70
80
90
100
110
Pressure (GPa)
Nomura et al., 2011
Liebske et al., 2005
Corgne et al., 2005
Ito et al., 2004
Walter et al., 2004
Tronnes and Frost, 2004
Hirose et al., 2004
Ohtani et al., 1998

Wood and Rubie, 1996

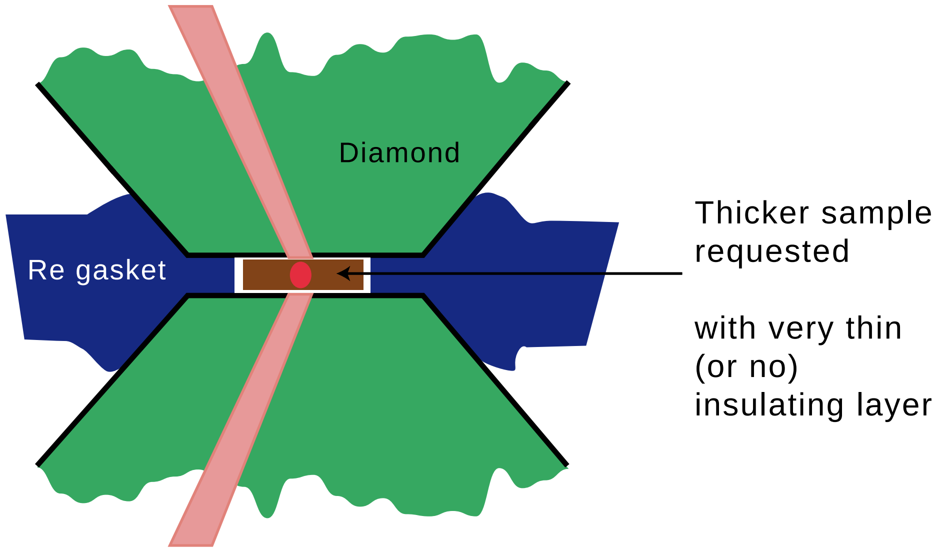


Lauterbach et al., 2000



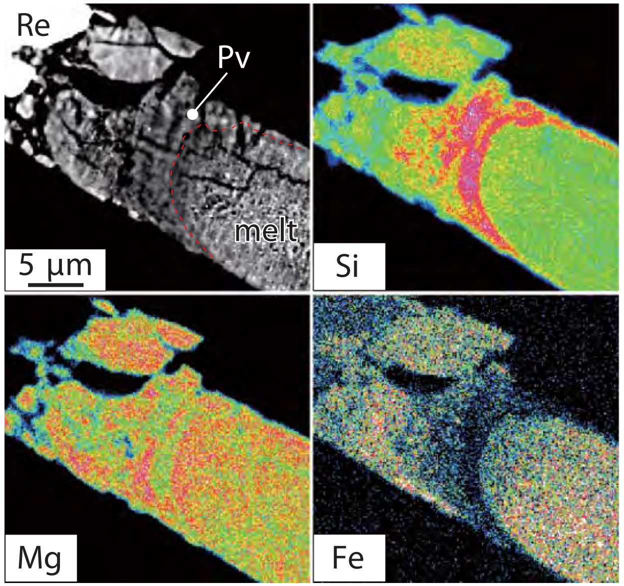
=> Strong structural interactions between Al and Fe in the perovskite structure

Axial cut



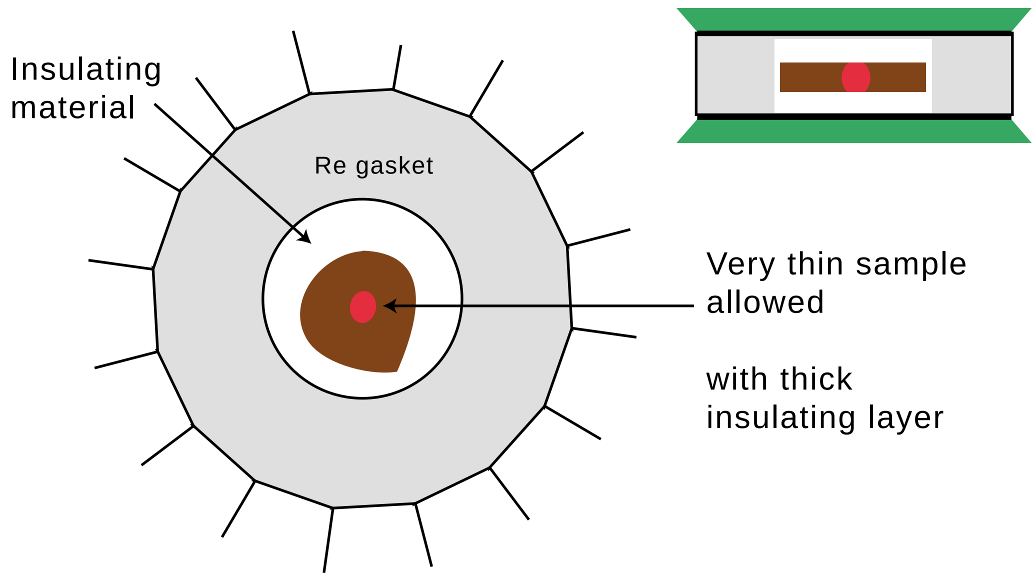
Cut axially using FIB or Ion Slicer

76 GPa



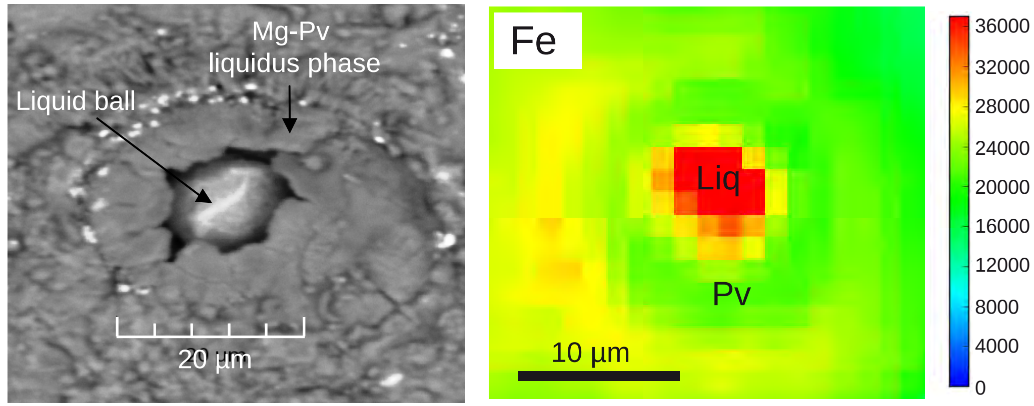
Nomura et al. , 2011

Radial scan



Can be studied as it is, in situ,
or after removal of the insulating material

78 GPa

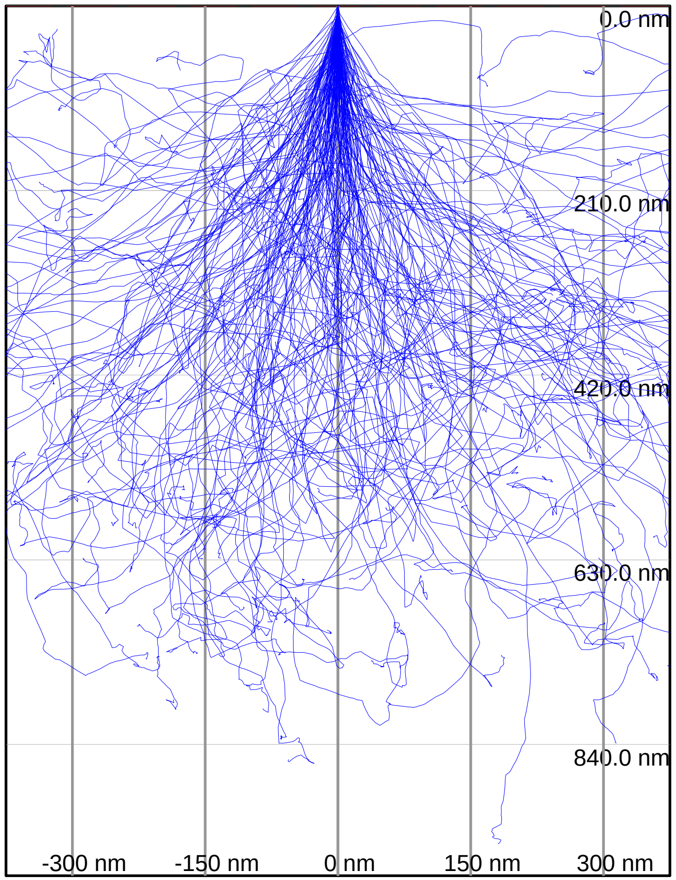


Analytical conditions for FEG-EPMA analysis in Nomura et al., 2011

Analytical conditions for XRF analysis in this study

Using electrons

Beam size 1nm ; Energy: 10 KeV; (Mg,Fe)SiO3



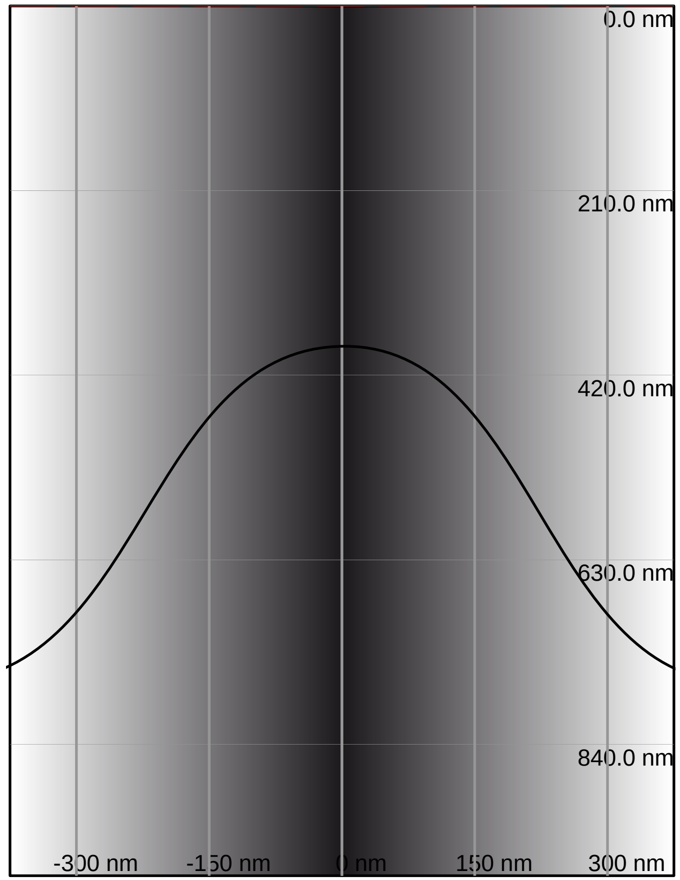
0.8 microns

Spatial resolution

A special dedicace to Stephane Labrosse

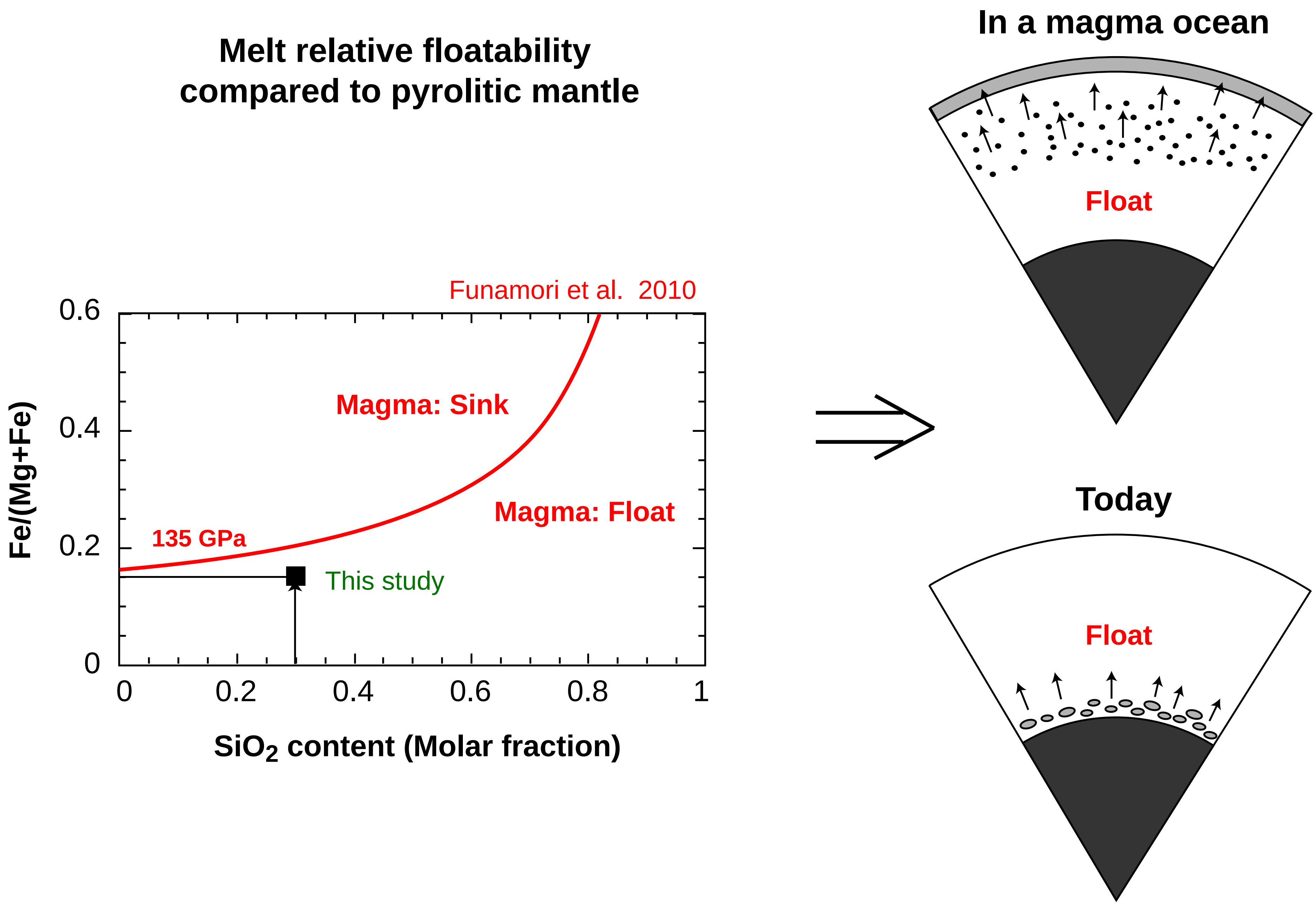
Using X-rays on ID21 beamline

Beam size 0.5 microns ; Energy: 7.2 KeV



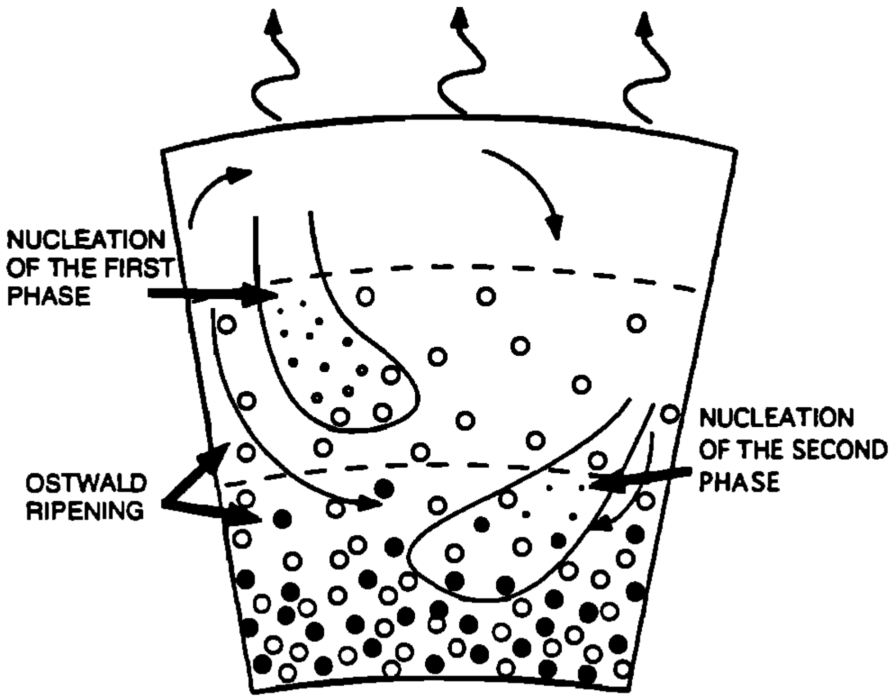
0.5 microns

Spatial resolution



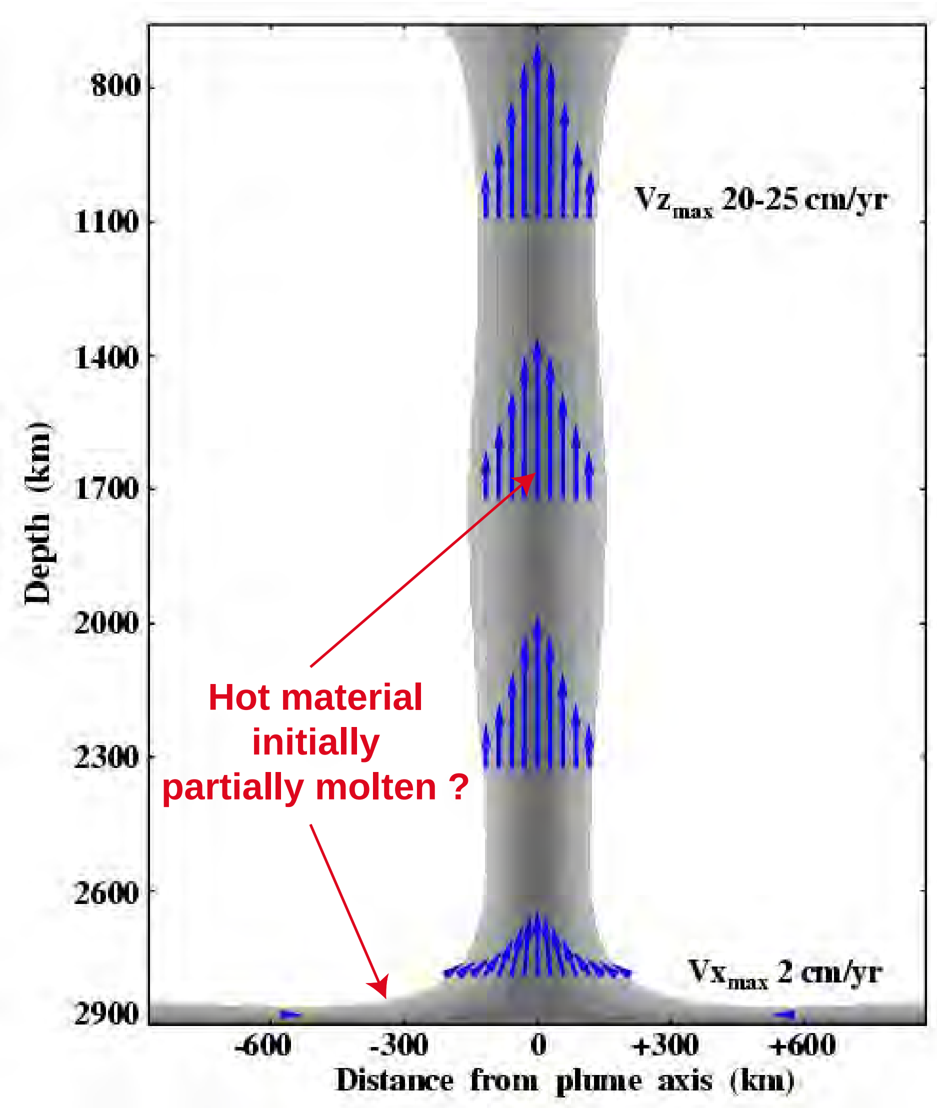
Melt relative floatability
compared to pyrolitic mantle
Funamori et al. 2010
0.6
0.4
0.2
0
Fe/(Mg+Fe)
Magma: Sink
Magma: Float
135 GPa
This study
0
0.2
0.4
0.6
0.8
1
SiO_2 content (Molar fraction)
In a magma ocean
Float
Today
Float

In the magma ocean



Solomatov and Stevenson, 1993

In the actual mantle



Farnetani et al., 2002

CONCLUSIONS

Does partial melting occurs today in the D”-layer ?

Not if “classical” lower mantle temperature profiles are true.

Could be possible if

- the core is extremely hot; more than 4150 K at the CMB
- fusible elements are concentrated in this mantle region

What would happen to the liquids ?

They would tend to rise toward the surface

And then ?

- A liquid pocket rising in the mantle may cristallize fast
- The liquids can be engaged in a larger uprising movement
- Solidification and loss of Pv grains will favor uprising