Heat and Mass Flux: The Role of the Core

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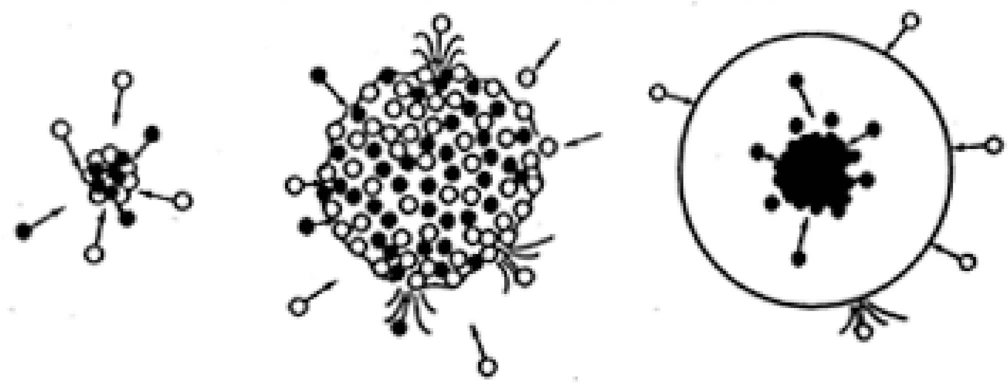
Outline

- ❑ Introduction
- ❑ Temperature of the Core
- ❑ Light elements in the core
- ❑ Age of the Inner core
- ❑ Radioactive elements in the core
- ❑ Conclusions

Role of Core in Heat and Mass flux

- Core formation



- Inner core growth
- Discovery of the core
  - Core: Oldham, 1906
  - Inner core: Lehmann 1935

The State of the Core

1 GPa = 10^4 bar

Size:

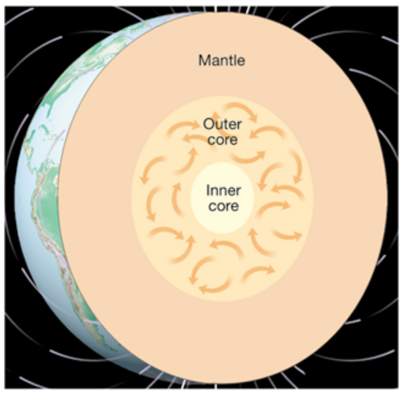
radius	**3480 km (1/2 Earth)**
volume	**1/8 Earth**
mass	**1/3 Earth**

Properties:

density	**10-13 g/cm^3**
pressure	**136-330 GPa**
temperature	**5500±1500 K**
state	**liquid-solid**

Composition: **iron-nickel**

The Dynamics of the Core



1 Ga = 10^9 year

<u>Core-Mantle Boundary</u>

Core formation **~ 4.5 Ga**

<u>Outer Core</u>

Convection **Geodynamo**

<u>Inner-Outer Core Boundary</u>

Secular cooling

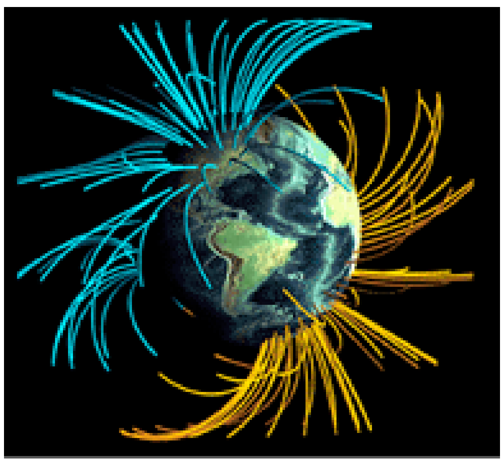
Radioactive decay?

<u>Inner Core</u>

Differential rotation

Anisotropy

The Mysteries



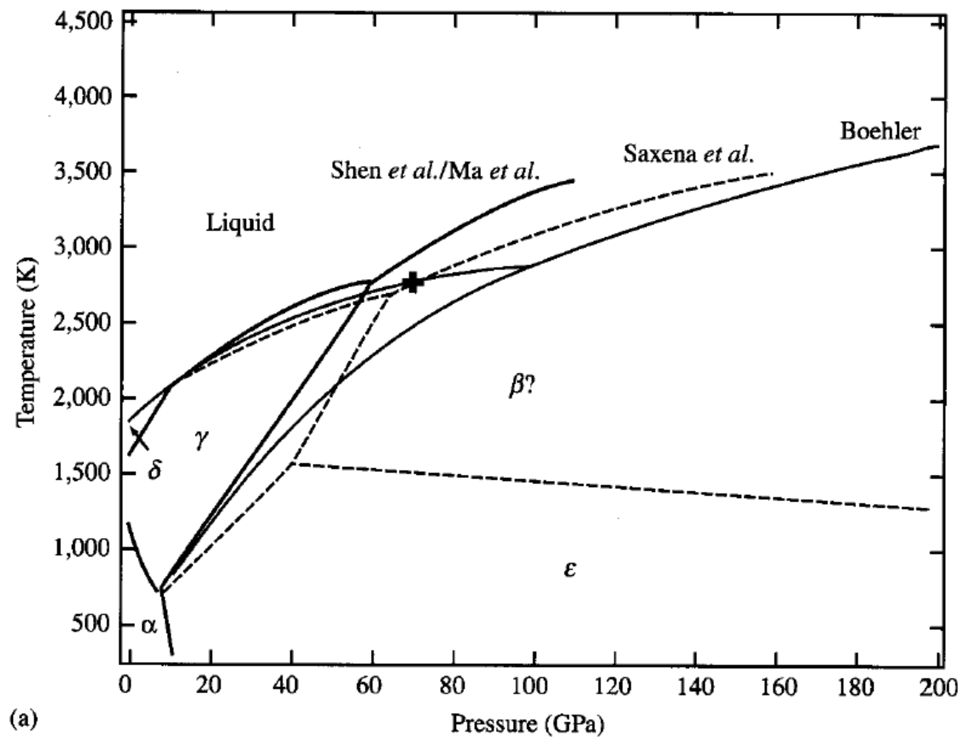
- **Core formation**
  - ***Homogeneous or Heterogeneous accretion?***
- **Temperature**
- **Density deficit**
  - ***Light elements in the core?***
- **Geodynamo**
  - ***Thermal or chemical convection?***
- **Inner core differential rotation**
- **Inner core anisotropy**

Temperature of the core

- Temperature at the CMB
  - Upper limit: Solidus of the mantle
  - Lower limit: Liquidus of the core
  - Additional constraint: Adiabat of the core

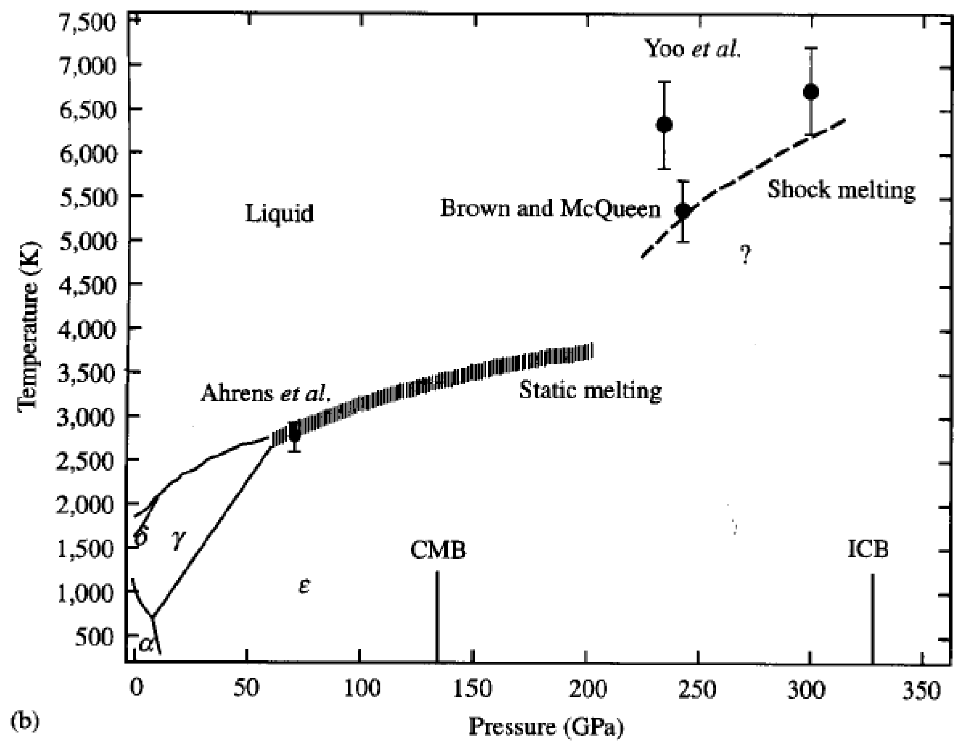
- Temperature at the ICB
  - Solid-liquid boundary of the core

Temperature at the ICB



Cross: Ahren et al. 2002

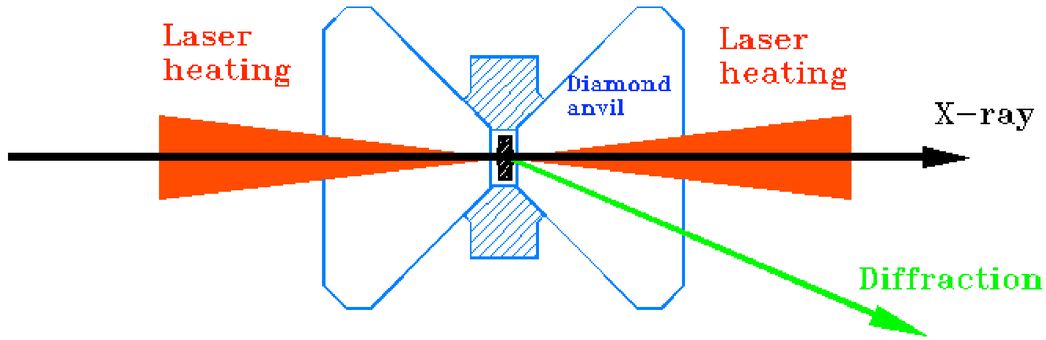
Temperature at the ICB

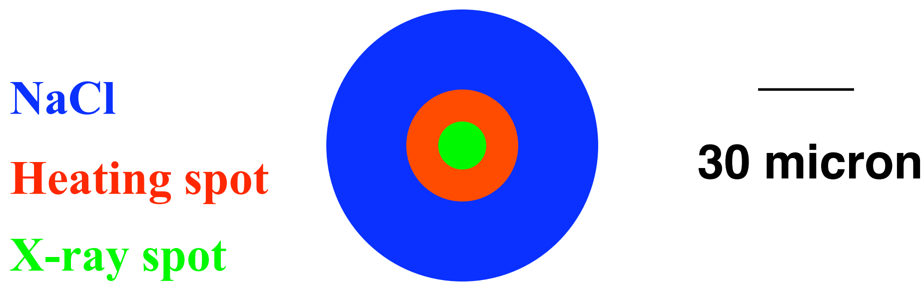


Sources of Uncertainties

- ❑ Generate pressure
  - High pressure and diamonds
  - Pressure gradient
  - Non-hydrostatic pressure
- ❑ Measure pressure
- ❑ Generate temperature
  - High temperature and laser
  - Temperature gradient
- ❑ Measure temperature
- ❑ Melting criteria

Measuring Melting Temperature

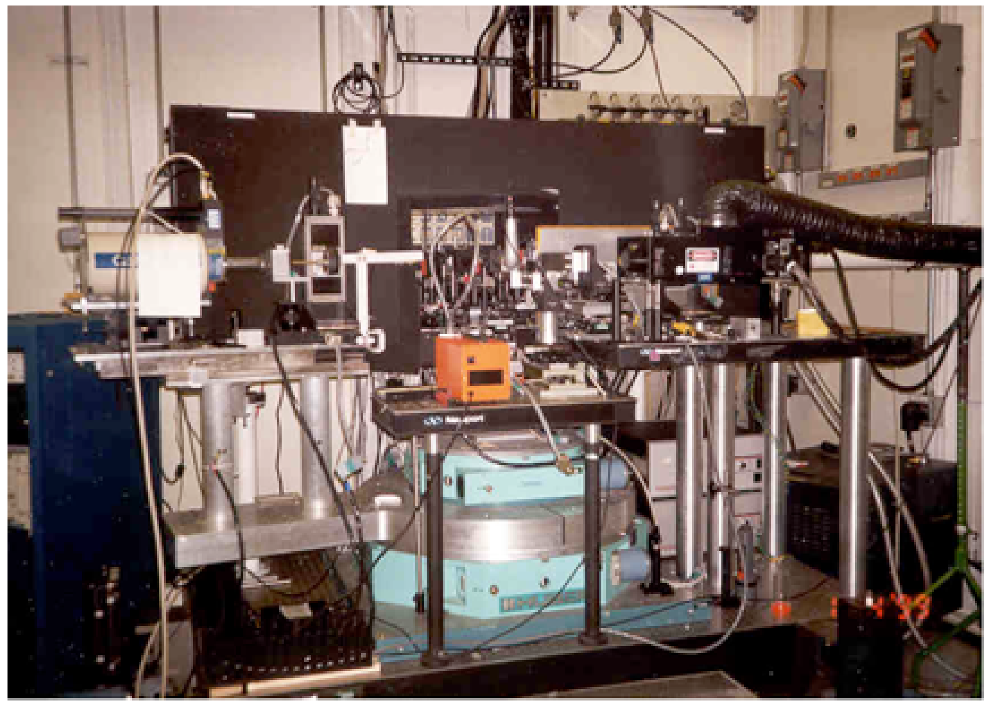




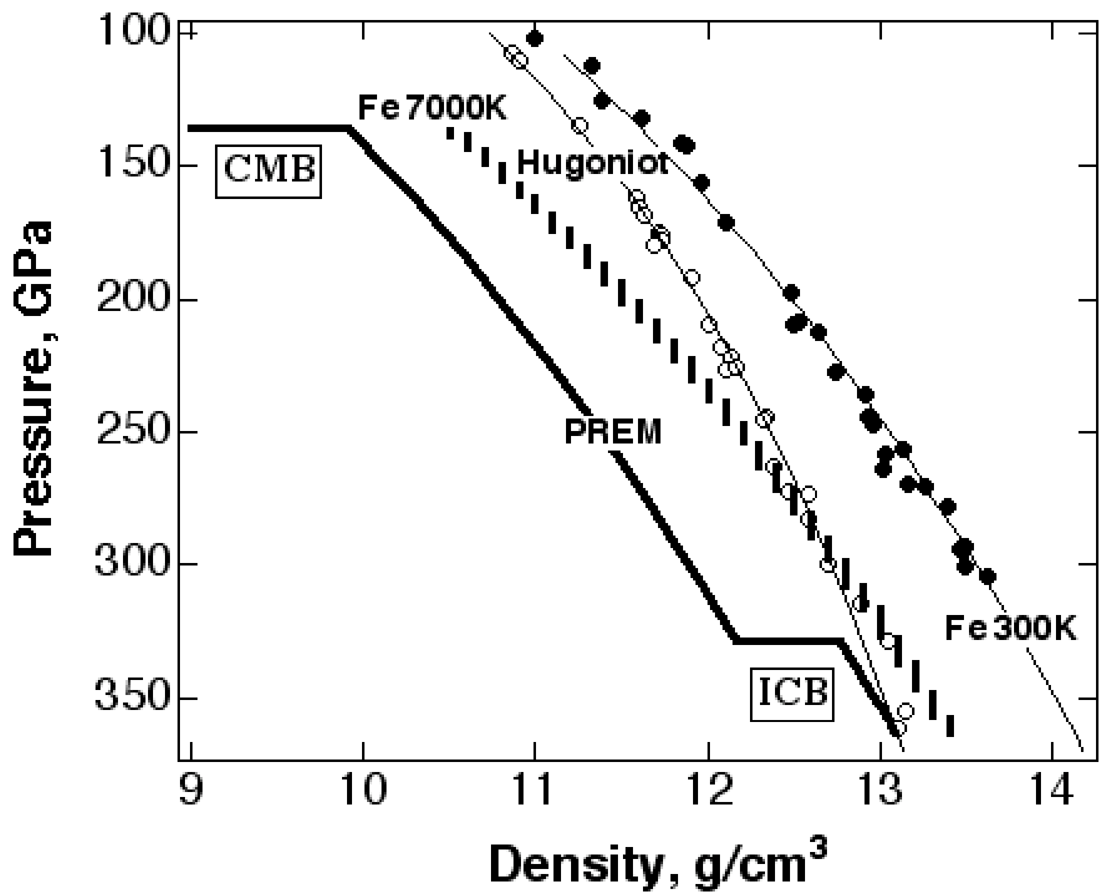
Measuring melting temperature

Advanced Photon Source

GSECARS



Density Deficit in the Core



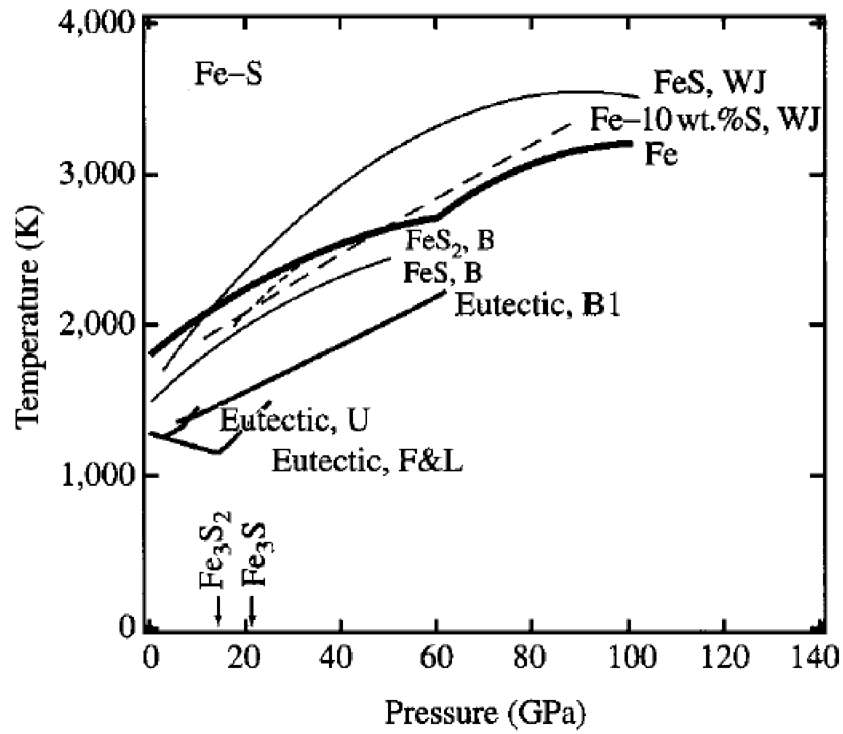
Light elements in the Core

- Major criteria
  - Abundant in the Earth
  - Affinity to iron
  - Reproduce density deficit
  - Reproduce seismic velocities
  - Lower the melting point (prefers OC)

- Major candidates

  H, C, O, S, Si

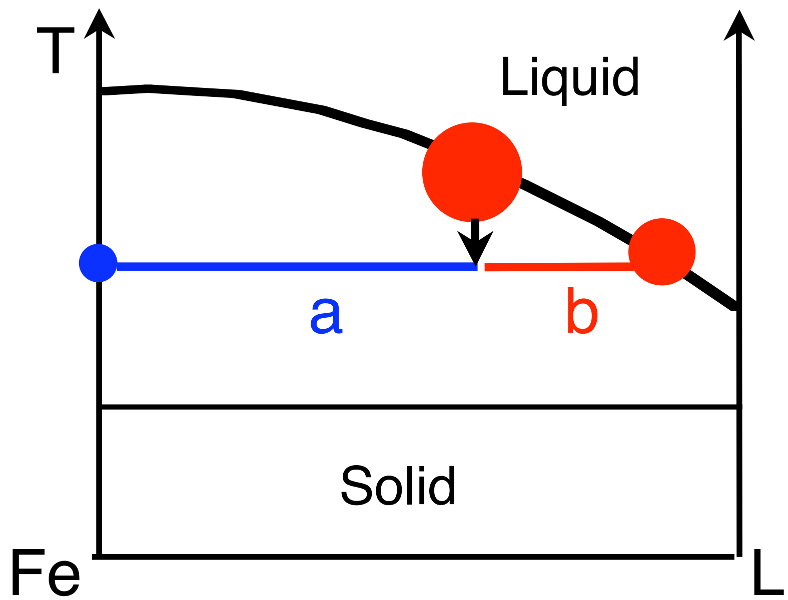
Light elements on ICB Temperature



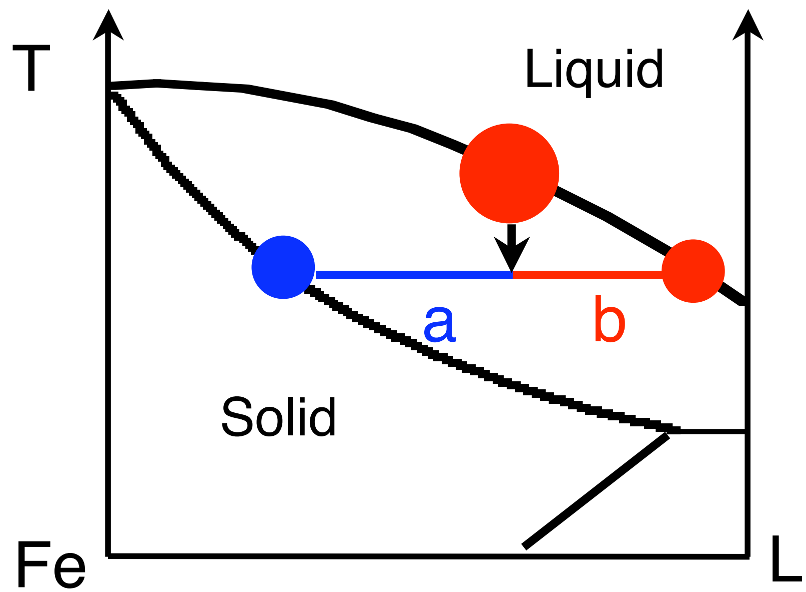
Li et al. 2003

Chemical Buoyancy at ICB

Inner Core is Pure Fe



Light element in the Inner Core



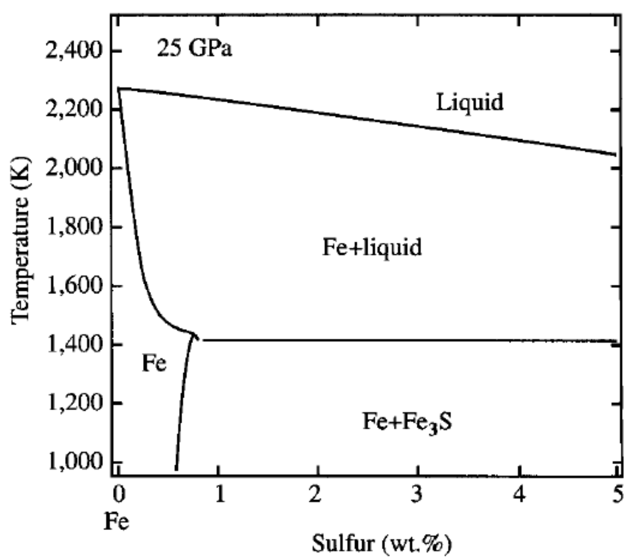
original liquid = derived liquid + derived solid

$\Delta\rho$ liquid = curvature of liquidus

% derived liquid = a/(a+b)

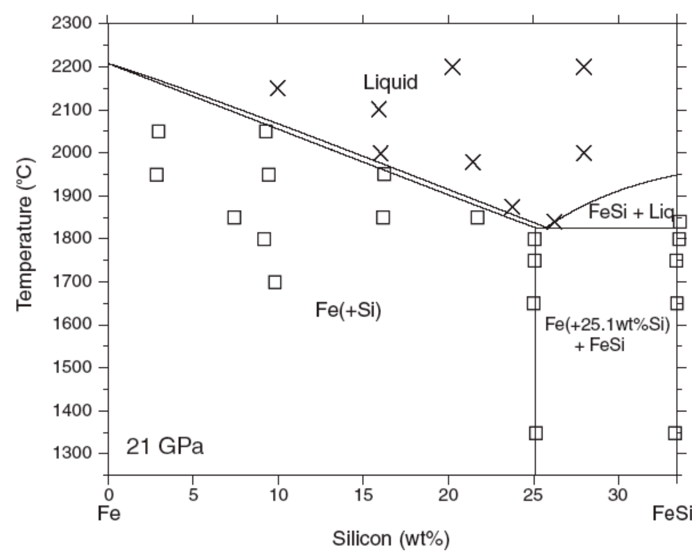
Light Elements on Convection

Fe-S



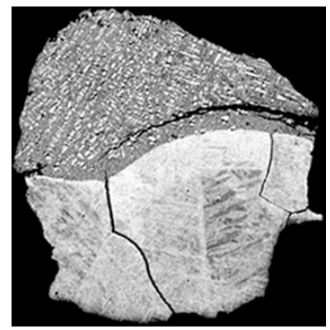
Li et al. 2001

Fe-Si



Kuwayama & Hirose 2004

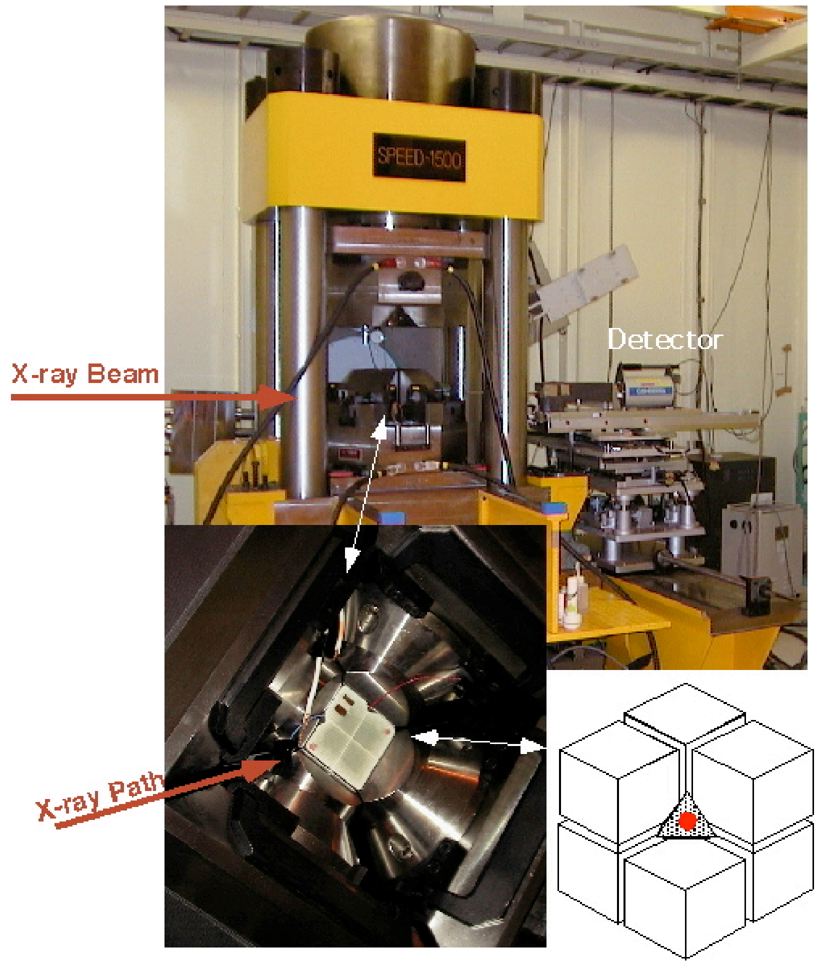
Determine Phase Relations



Multi-Anvil Apparatus
Geophysical Laboratory

In situ measurements

Himeji Castle



Age of the Inner Core

Constraints:

Current size of the inner core

Geodynamo is older than 3.5 Ga

Larosse et al. 2001
Buffett 2002

Inner core old, slow growth, little heat for geodynamo

➢ Geodynamo is not driven by inner core growth

Inner core young, fast growth, much heat for geodynamo

➢ Geodynamo is not driven by inner core growth before inner core formation

➢ Geodynamo can exist without inner core

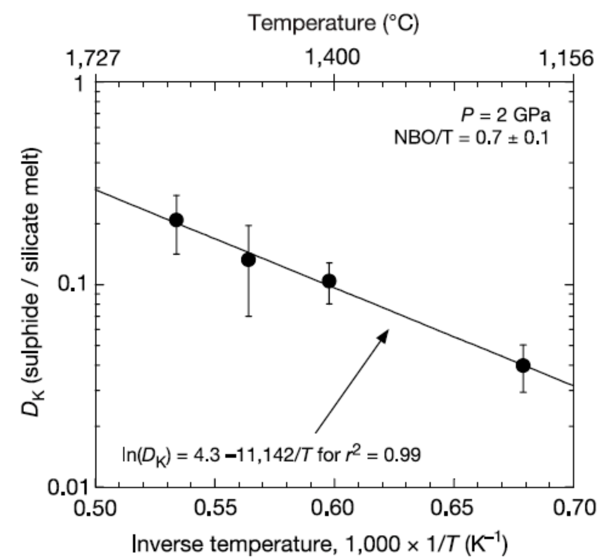
? Radioactive heat source in the core

Radioactive Elements in the Core

NATURE | VOL 423 | 8 MAY 2003 | www.nature.com/nature

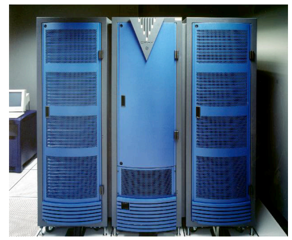
Experimental evidence that potassium is a substantial radioactive heat source in planetary cores

V. Rama Murthy*, Wim van Westrenen†‡ & Yingwei Fei†

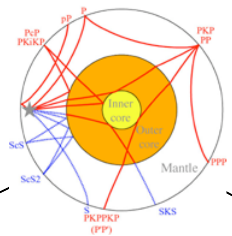


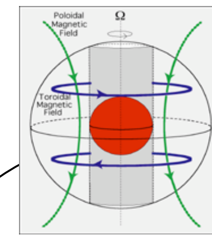
60 to 130 ppm K in the core = 0.4 to 0.8 TW heat at CMB

Future Perspective



Mineral Physics





Geophysical & Geochemical observations

Experimental Geochemistry

Earth models