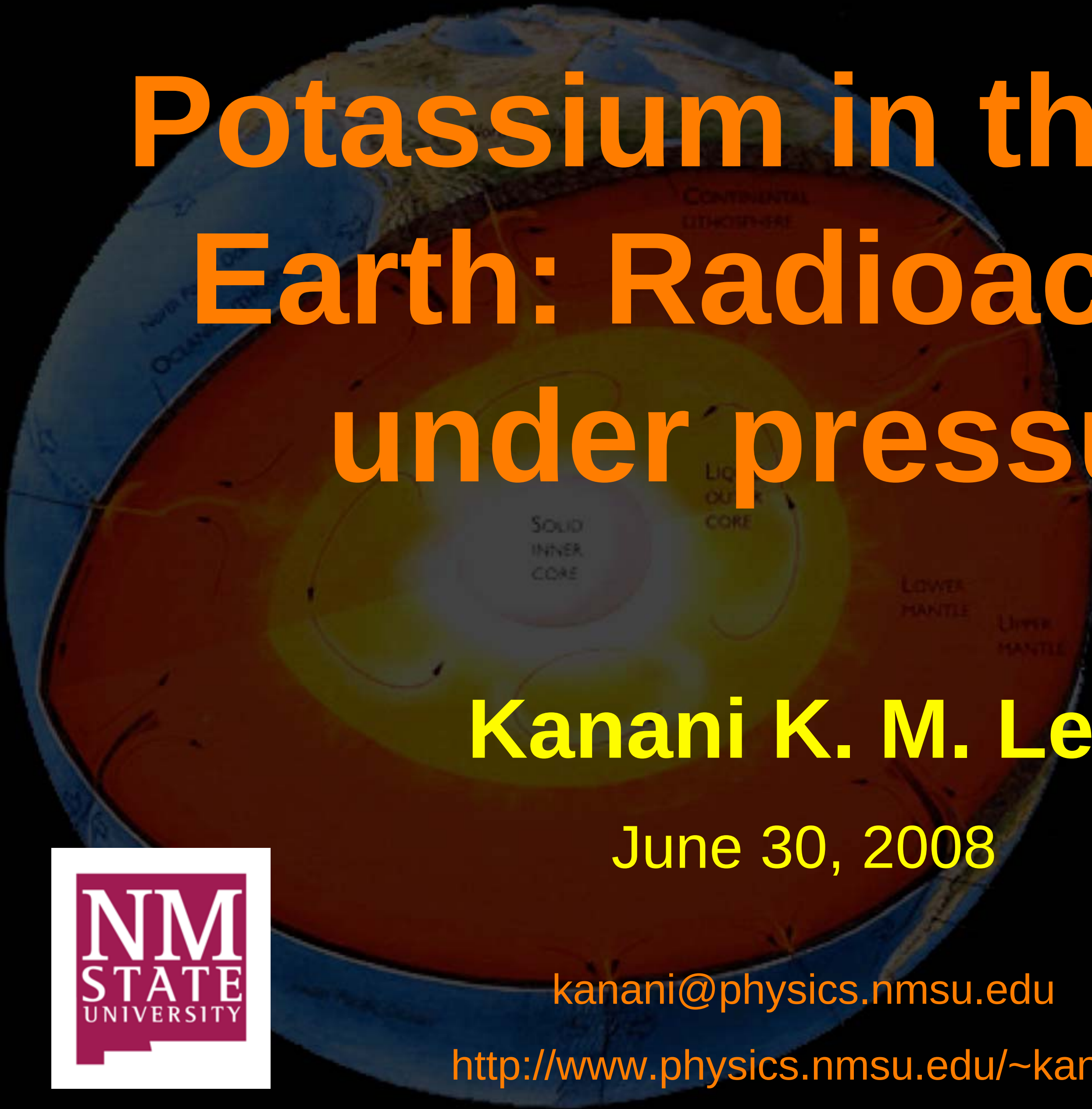


Potassium in the deep Earth: Radioactivity under pressure

Kanani K. M. Lee

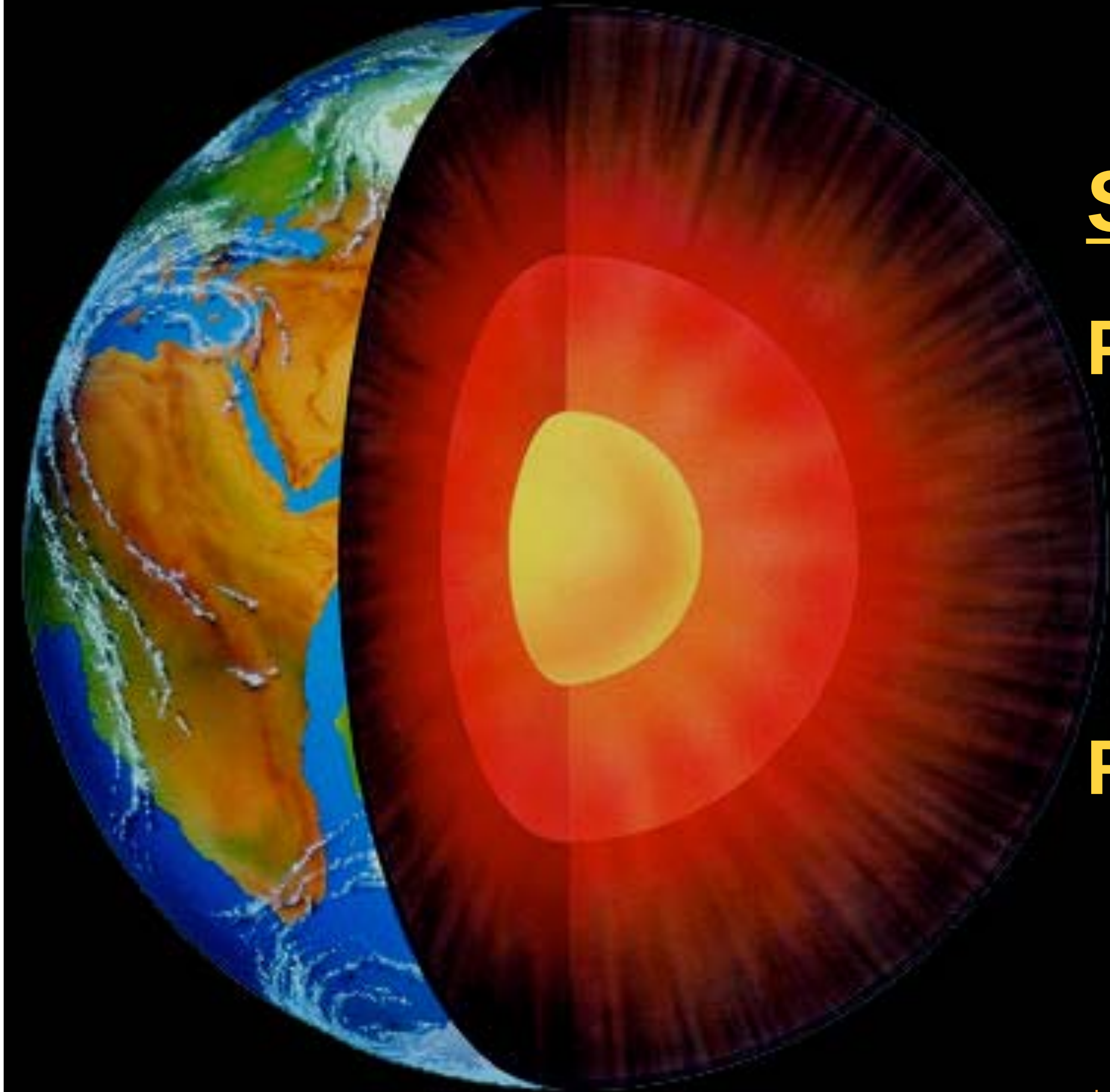
June 30, 2008

kanani@physics.nmsu.edu

http://www.physics.nmsu.edu/~kanani

Collaborators: Gerd Steinle-Neumann, Sofia Akber-Knutson, David Dolenc

Heat → Dynamics



<u>SOURCES</u>

Primordial:

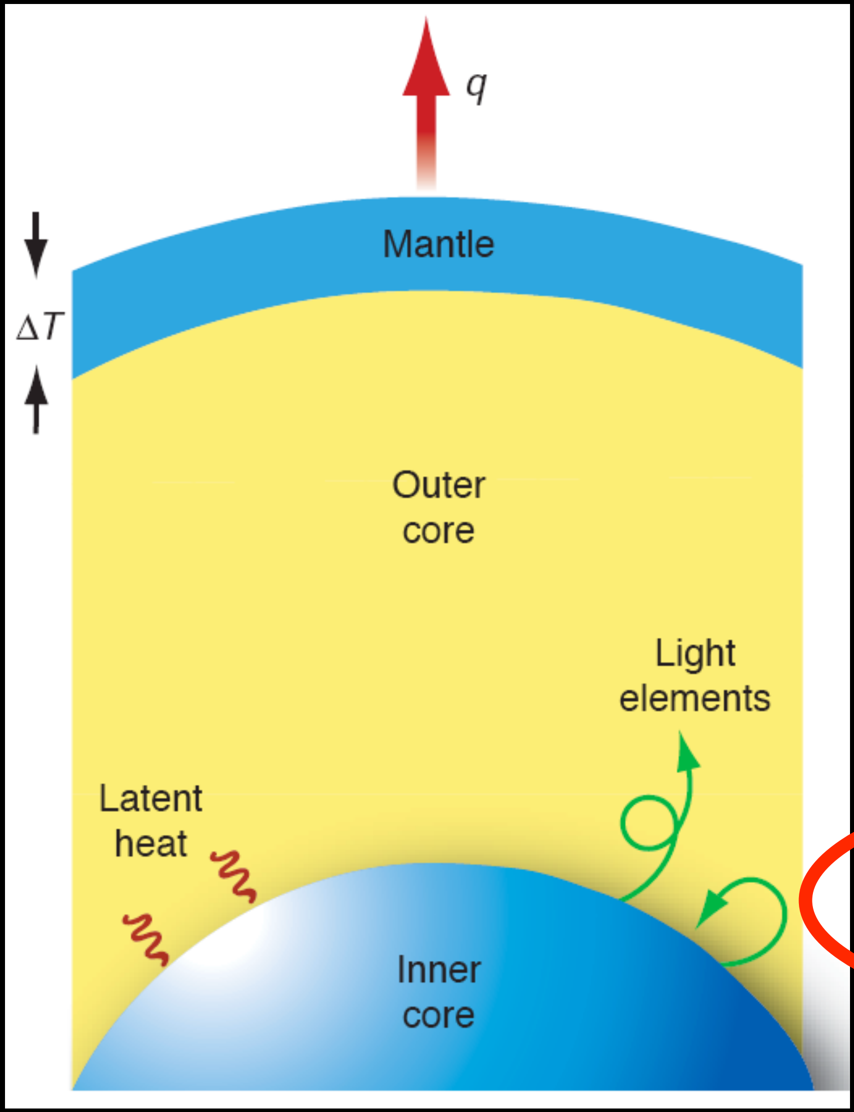
- **accretion**
- **differentiation**

Radioactivity:

- **K, U, Th**

www.gridclub.com/fact_gadget/ 1001/earth/earth/99.html

Geodynamic motivation



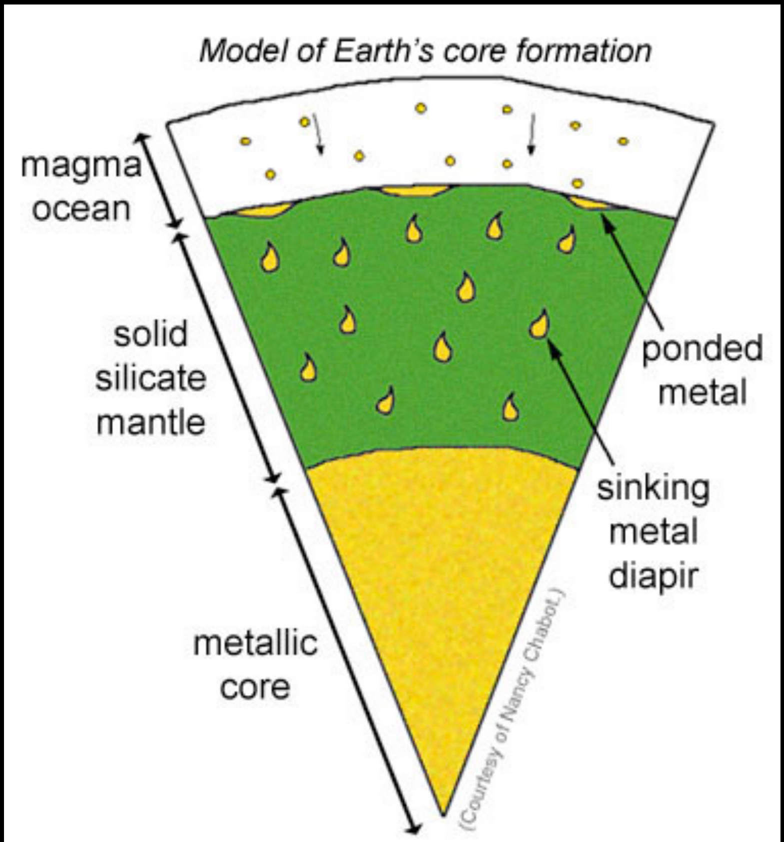
(Buffett, 2003)

Buoyancy forces powering dynamo:
- Secular cooling
- Chemical buoyancy
- Latent heat release

Superheating of core before 2 Ga.
Geodynamo paradox in the young Earth?

Solutions:
- Power requirements of the dynamo smaller than 1 TW. (Christensen and Tilgner, 2004)
- Radioactive heat sources in core.
- Radioactive elements accumulated near CMB.

Potassium in the deep Earth



K in the core:

- partitioning during core formation
- partitioning at CMB

(e.g. Ito et al., 1993; Gessmann and Wood, 2002; Murthy et al., 2003)

K in the deep mantle:

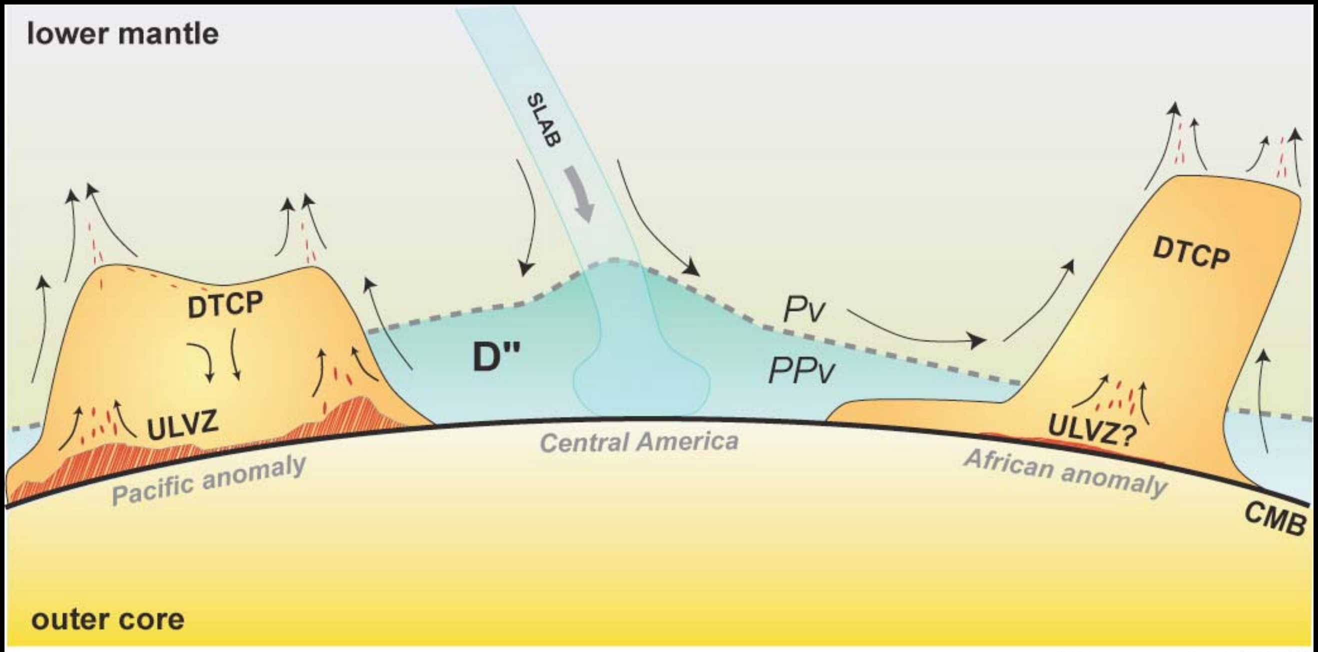
- partitioning between LM phases
- dynamic stability of possible reservoir (McNamara and Zhong, 2004; Farnetani, 1997)

Geochemical constraints:

- silicate Earth depleted in K relative to chondrites
- degree of volatile loss unclear

  (Humayun and Clayton, 1996)
- concentration of K in mantle *low*, separate phase unlikely to exist.

Possible reservoirs in the deep Earth



[Garnero et al. [2006]]

Reservoir	**K (U/Th) partitioning**
• core	Fe - mantle silicates
• lower mantle:D”	pv - ppv
DTCP/ULVZ	???

Approach

Energetics of chemical reactions over wide pressure range

Lower mantle:
with **M** = Fe, Al.

$$(Mg_{30}\mathbf{M}K)Si_{32}O_{96}[pv] + Mg_{32}Si_{32}O_{96}[ppv] \leftrightarrow$$
$$(Mg_{30}\mathbf{M}K)Si_{32}O_{96}[ppv] + Mg_{32}Si_{32}O_{96}[pv]$$

$$K_D \equiv \exp\left(\frac{-\Delta G}{k_B T}\right) = \frac{(x_{K,pv})(1 - x_{K,ppv})}{(x_{K,ppv})(1 - x_{K,pv})}$$

Core:
with A=32, 48, 96.

$$(Mg_{30}\mathbf{Fe}K)Si_{32}O_{96}[pv] + A\,\mathbf{Fe} \leftrightarrow$$
$$(Mg_{30}\mathbf{Fe}_2)Si_{32}O_{96}[pv] + \mathbf{Fe}_{A-1}K$$

$$K_D \equiv \exp\left(\frac{-\Delta G}{k_B T}\right) = \frac{(x_{K,pv})(1 - x_{K,Fe})}{(x_{K,Fe})(1 - x_{K,pv})}$$

Energetics

$$K_D \equiv \exp\left(\frac{-\Delta G}{k_B T}\right)$$

$G(P,T)=U+PV-TS$

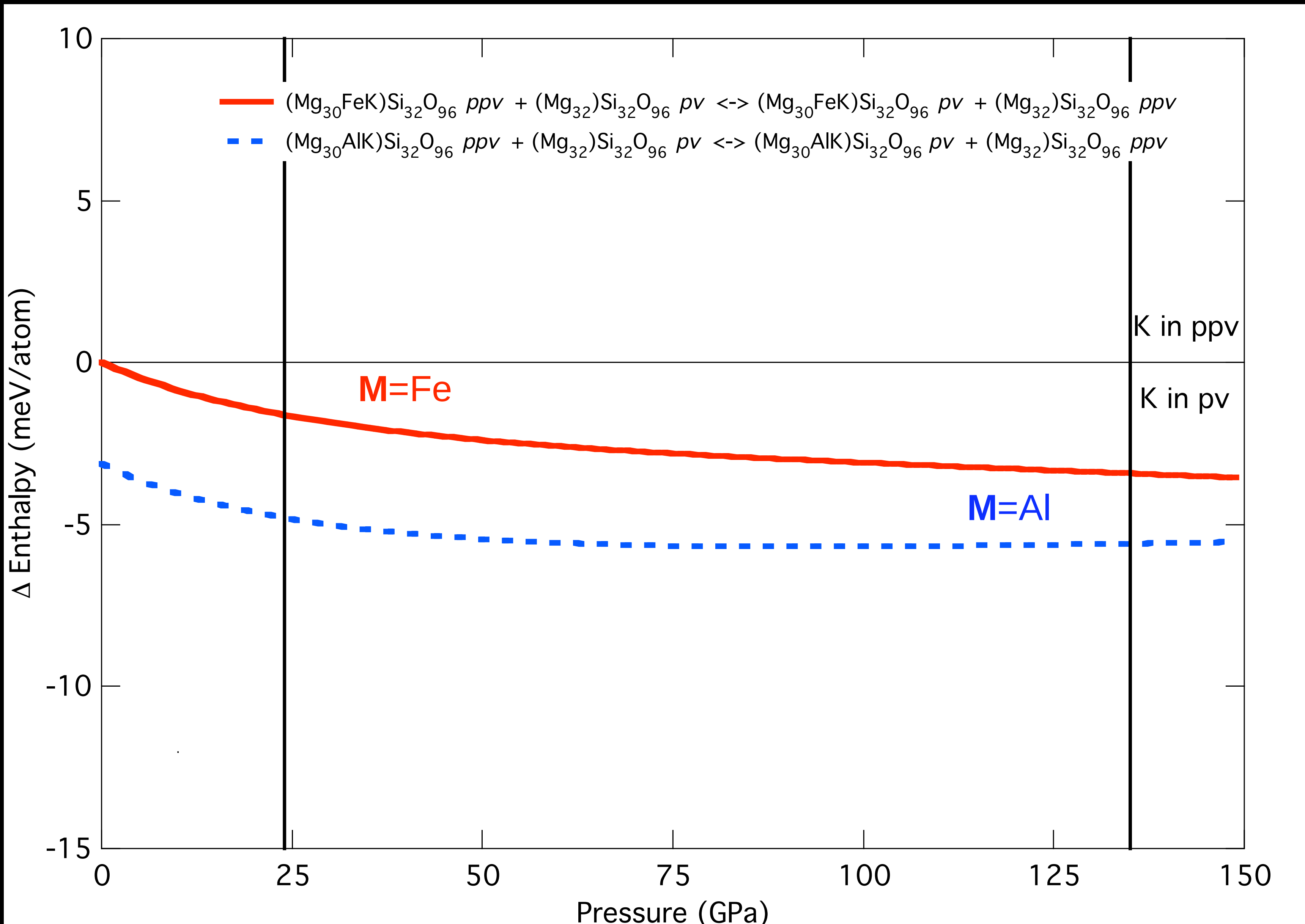
PV from cold equation of state

$S = S_{vib}+S_{mix}$

S_{mix} for Fe - silicate partitioning

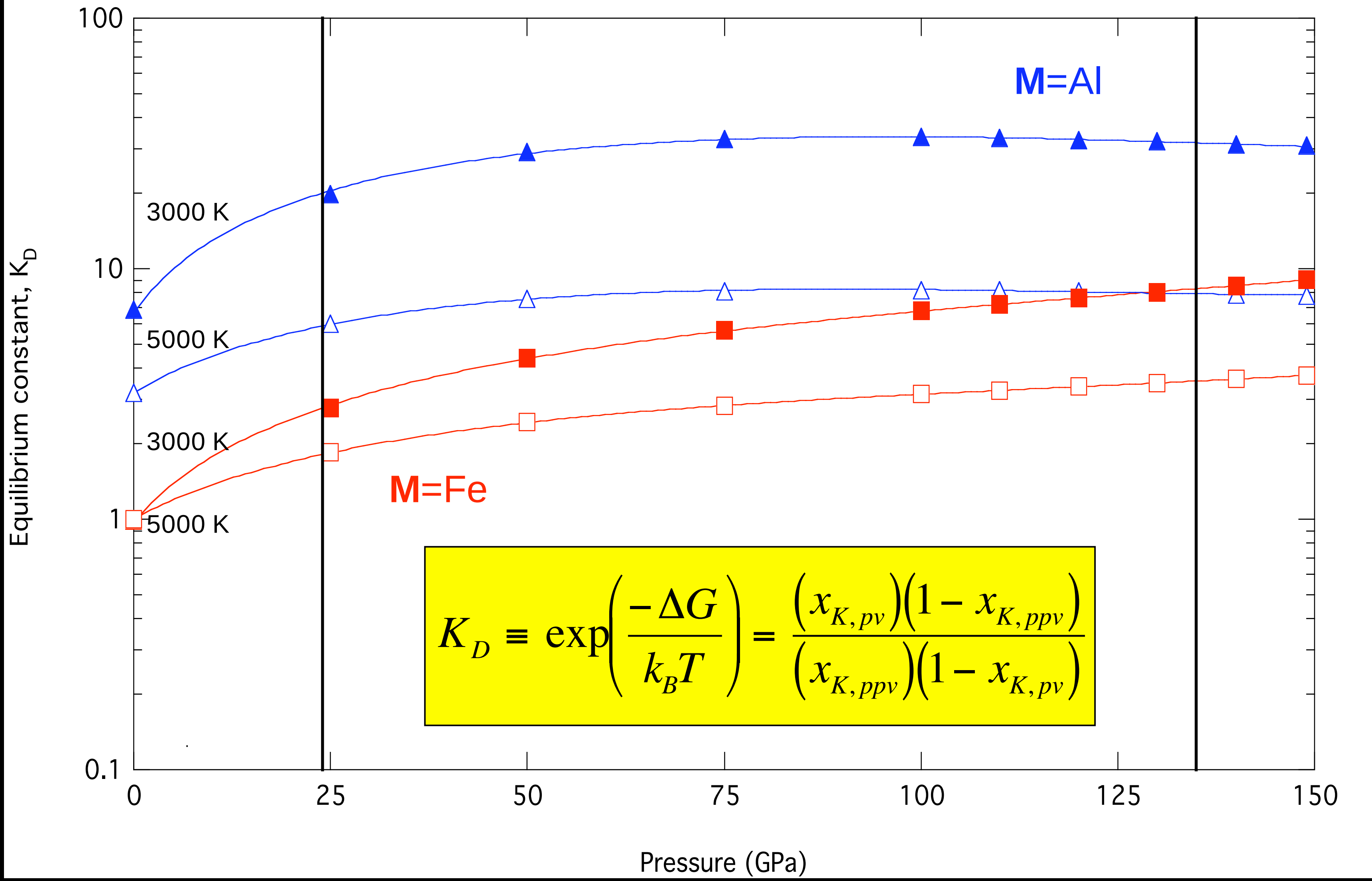
S_{mix} cancels for pv-ppv due to arrangements

Lower mantle partitioning



Lee et al., under review, 2008

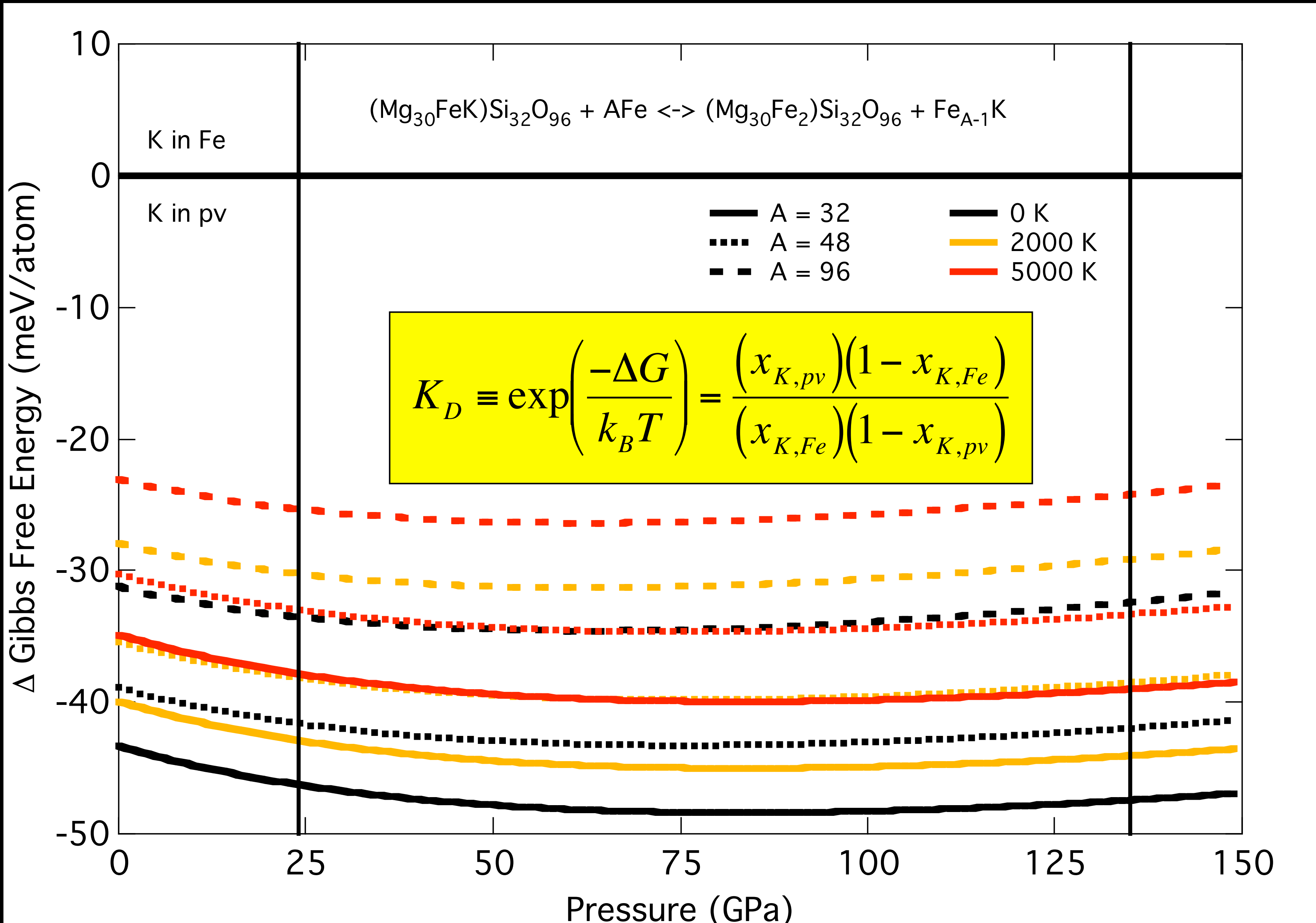
Lower mantle partitioning



$$K_D \equiv \exp\left(\frac{-\Delta G}{k_B T}\right) = \frac{(x_{K,pv})(1 - x_{K,ppv})}{(x_{K,ppv})(1 - x_{K,pv})}$$

Lee et al., under review, 2008

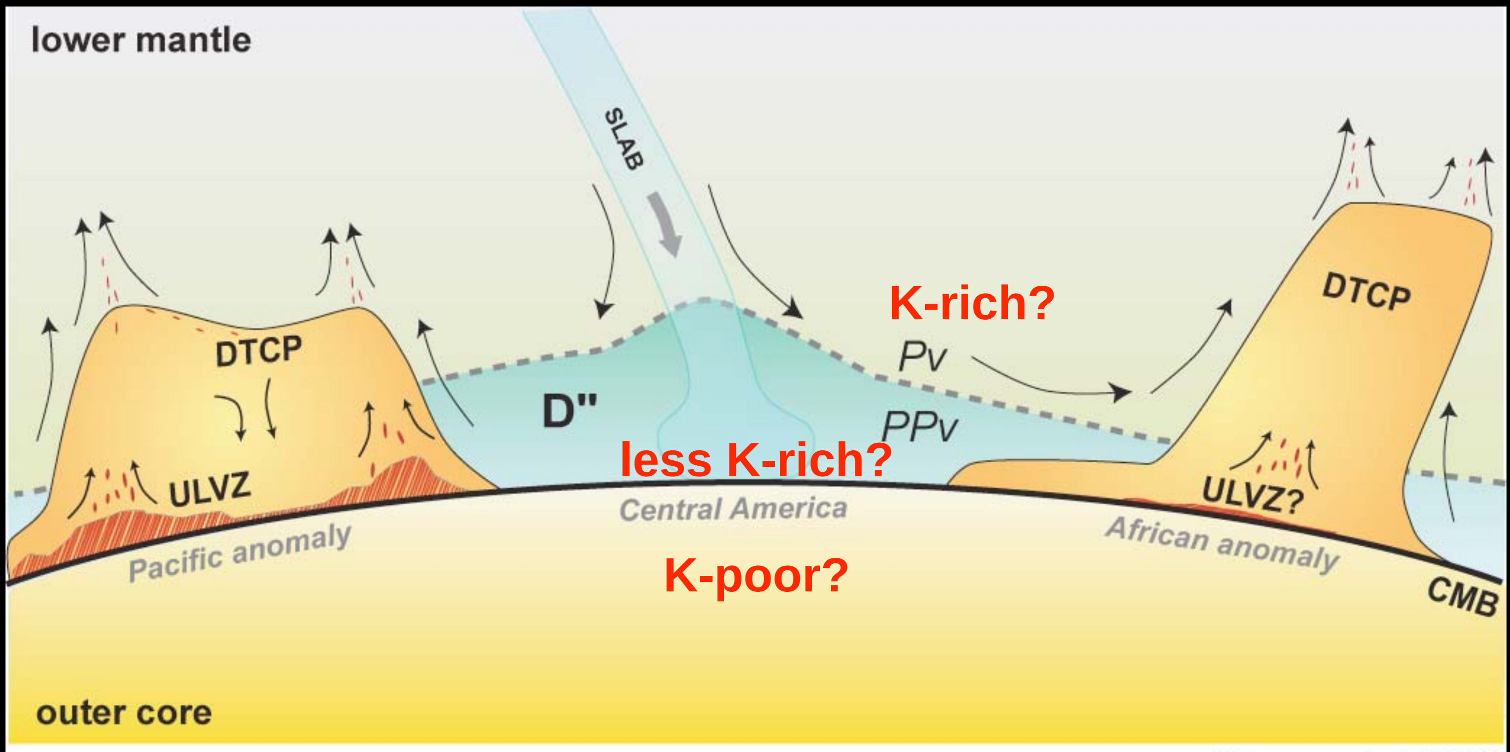
Core partitioning



Lee et al., in preparation, 2008

Conclusions: K partitioning in deep Earth

- Partitioning of K is favored in pv between Al- or Fe-bearing $MgSiO_3$ pv and ppv
- Partitioning of K is favored in pv between crystalline Fe-bearing $MgSiO_3$ pv and crystalline Fe



[Garnero et al. [2006]]

Conclusions: K partitioning in deep Earth

- Partitioning of K is favored in pv between Al- or Fe-bearing $MgSiO_3$ pv and ppv
- Partitioning of K is favored in pv between crystalline Fe-bearing $MgSiO_3$ pv and crystalline Fe

Caveats

- These are static computations!
- S_{vib} (Oganov and Price, 2005)
- Fe melt
- Role of light element in the core (O, S, Si) (Gessmann and Wood, 2002)
- Other incorporation mechanisms: oxygen vacancies?
- Other phases (MgO, $CaSiO_3$) (Tronnes and Frost, 2002; Murakami et al., 2005)

Supported by:
Alexander von Humboldt Foundation
Bayerisches Geoinstitut (Bayreuth)
CDAC (Department of Energy)
Los Alamos National Laboratory