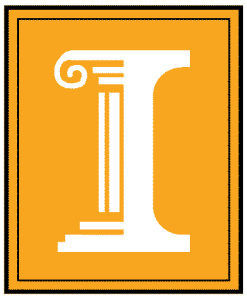
Transport Properties

Molecular Diffusion



Jie Jackie **Li**

University of Illinois at Urbana-Champaign

Mineral Physics

1-1-M July 14 2-3:30 pm (Kavner/Li) **Min. Phys 1** Overview of Earth Materials: Why is the transition zone a transition zone?

1-4-Th July 17 9-10:30am, 2-3:30pm (Kavner and Li) **Min. Phys 2** Experimental round-up! **Min. Phys Tutorial 1** What do mineral physics data look like?

1-5-F July 18 2-3:30pm **Min. Phys Tutorial 2** Earth Models.

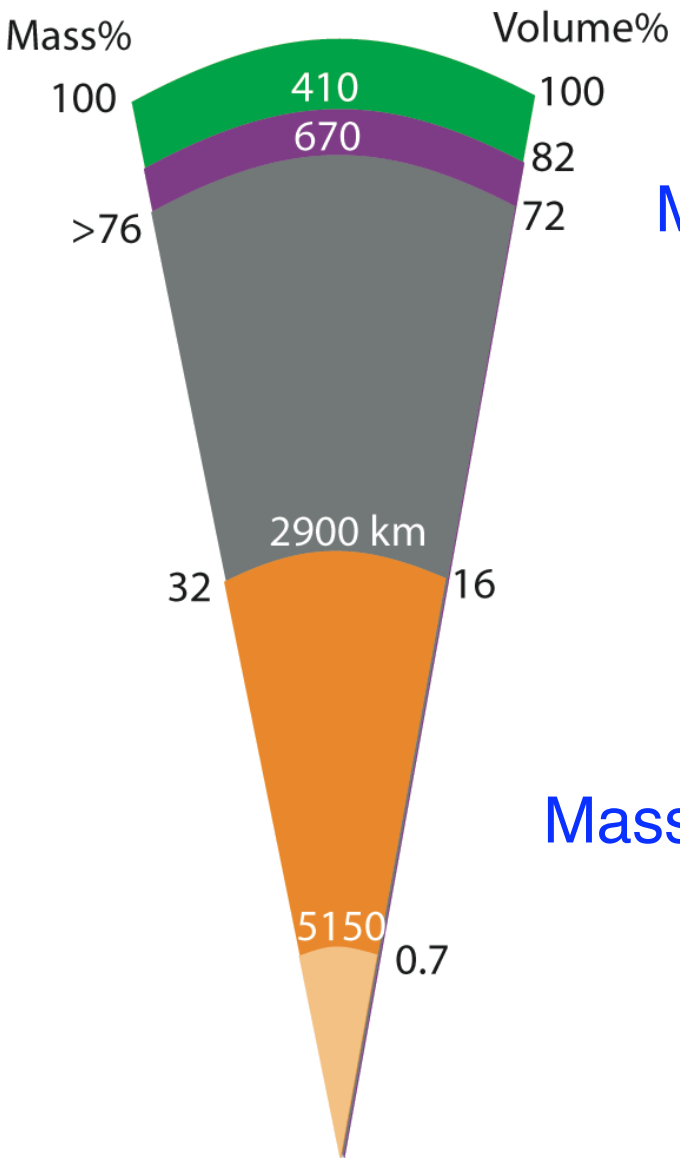
1-6-Sa July 19 9-10:30am (Li) **Min Phys 3** Mineral Physics of the Earth's core

2-9-W July 23 9-10:30am (Liebermann) **Min Phys 4** Elasticity of mantle minerals

2-10-Th July 24 9-10:30am (Li /Kavner) **Min Phys 5** Transport properties (Mass and heat)

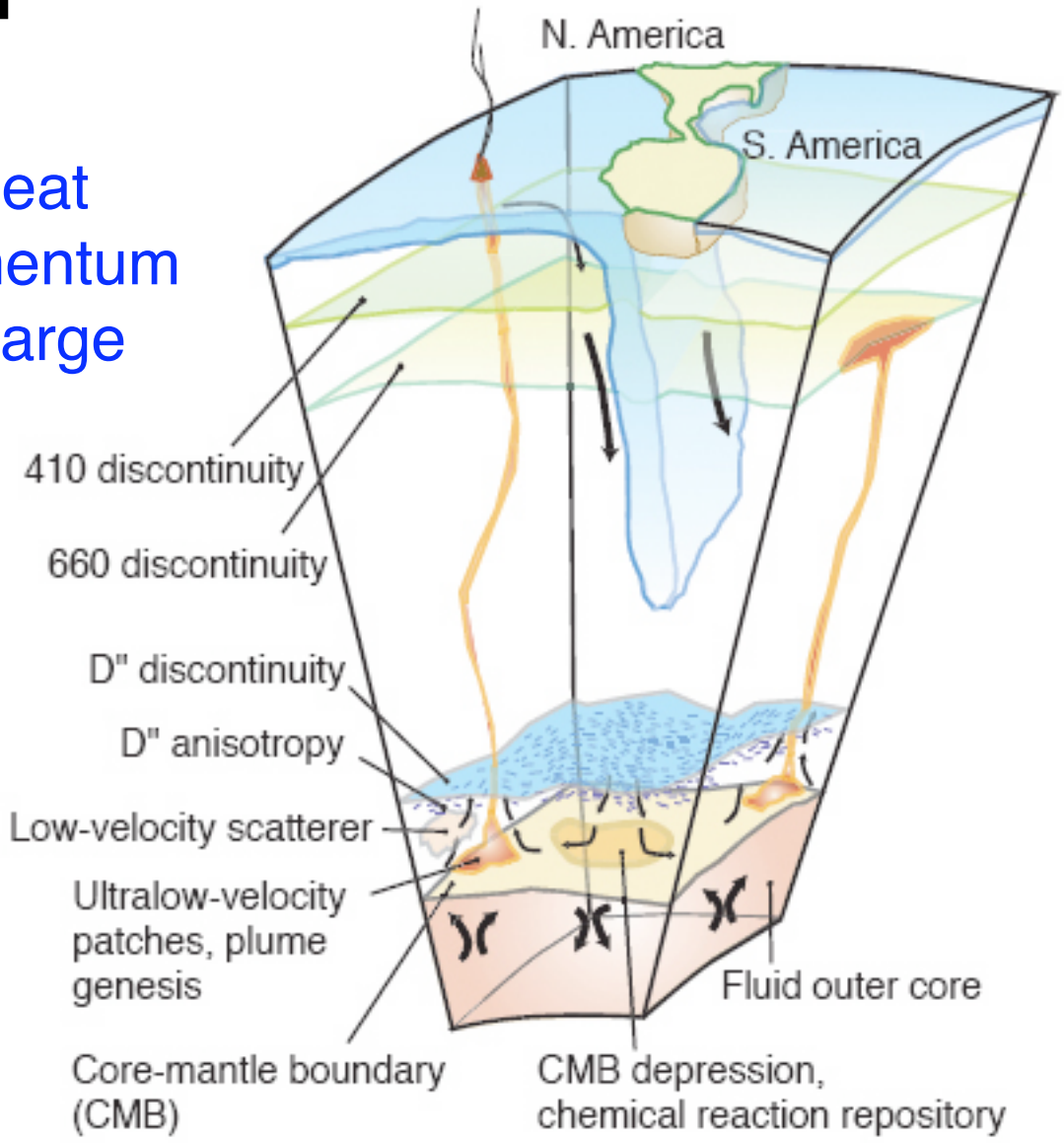
2-12-Sa July 26 9-10:30am (Kavner) **Min Phys 6** Boundaries and Interfaces

Transport Properties



Heat
Momentum
Charge

Mass



Garnero 04

Molecular Diffusion

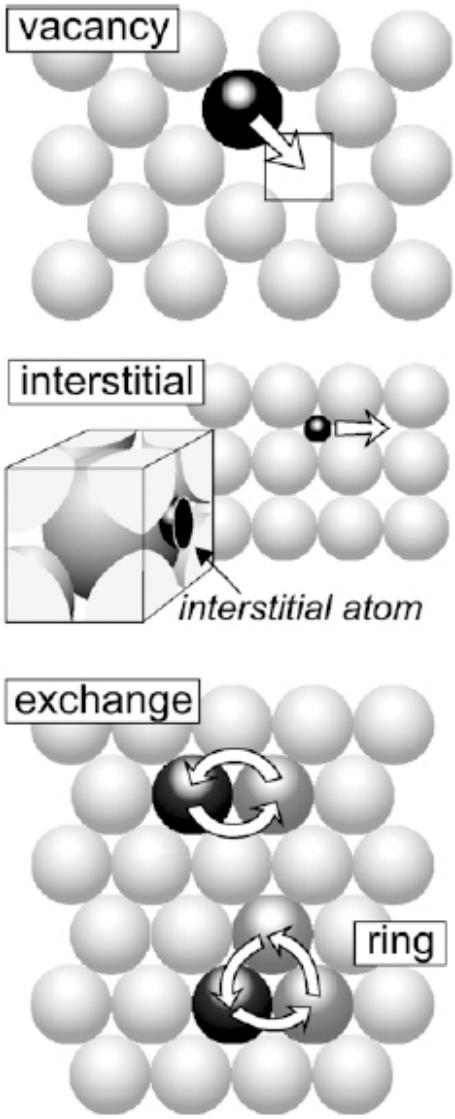
- Translational motion of atoms or molecules in a phase
- non-convective mass transport

Self diffusion (random walk, isotopic diffusion, tracer diffusion)
migration of the constituent atoms
in the absence of chemical gradients

Chemical diffusion
in a chemical potential gradient
inter-diffusion coefficient (binary system)

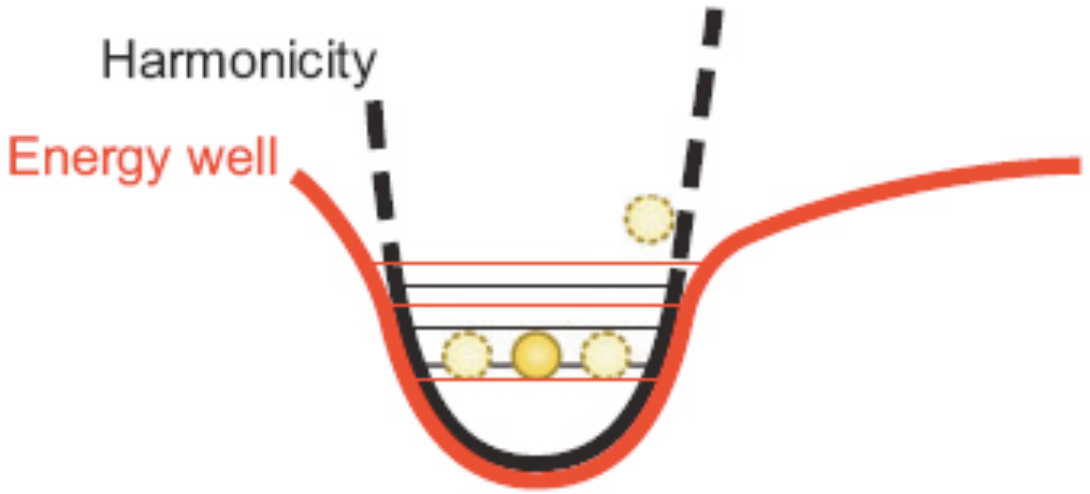
Watson & Baxter 07

Atomistic Approach



Jump frequency

$$\Gamma = \nu \exp(-E/kT)$$



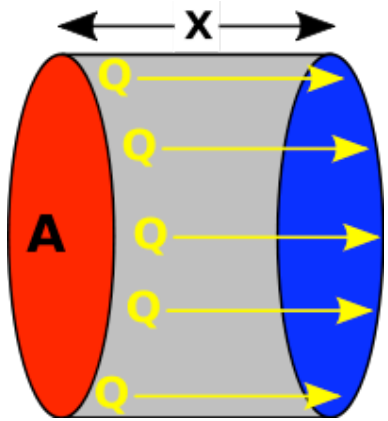
Watson & Baxter 07

Chakraborty 08

Empirical Approach (Phenomenology)

Fick's First Law: steady-state

$$J_i = -D_i \cdot \frac{\partial c_i}{\partial x}$$

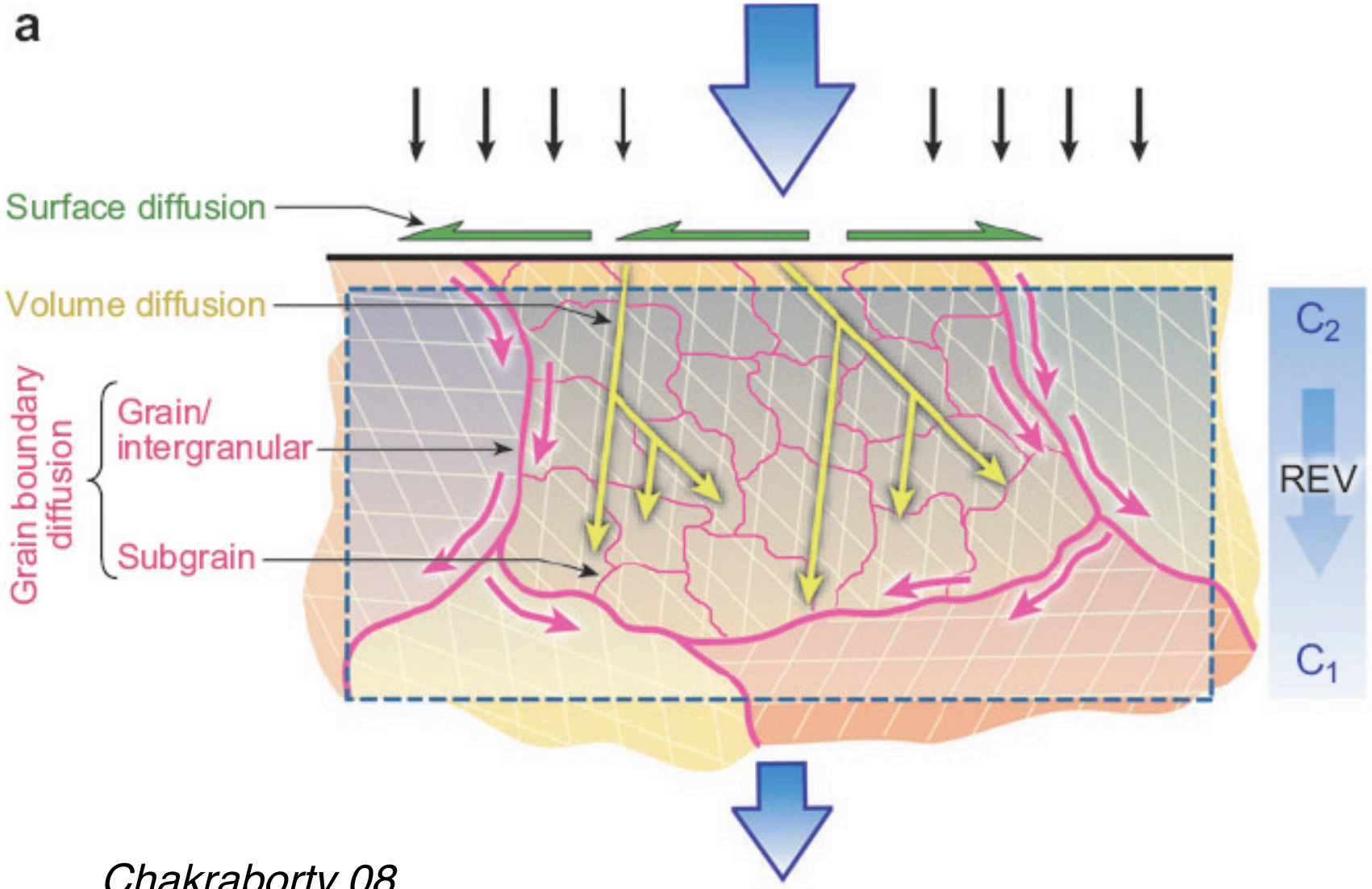


Fick's Second Law: non-steady-state

$$\frac{\partial c_i}{\partial t} = D_i \cdot \frac{\partial^2 c_i}{\partial x^2}$$

Watson & Baxter 07

Diffusion Pathways

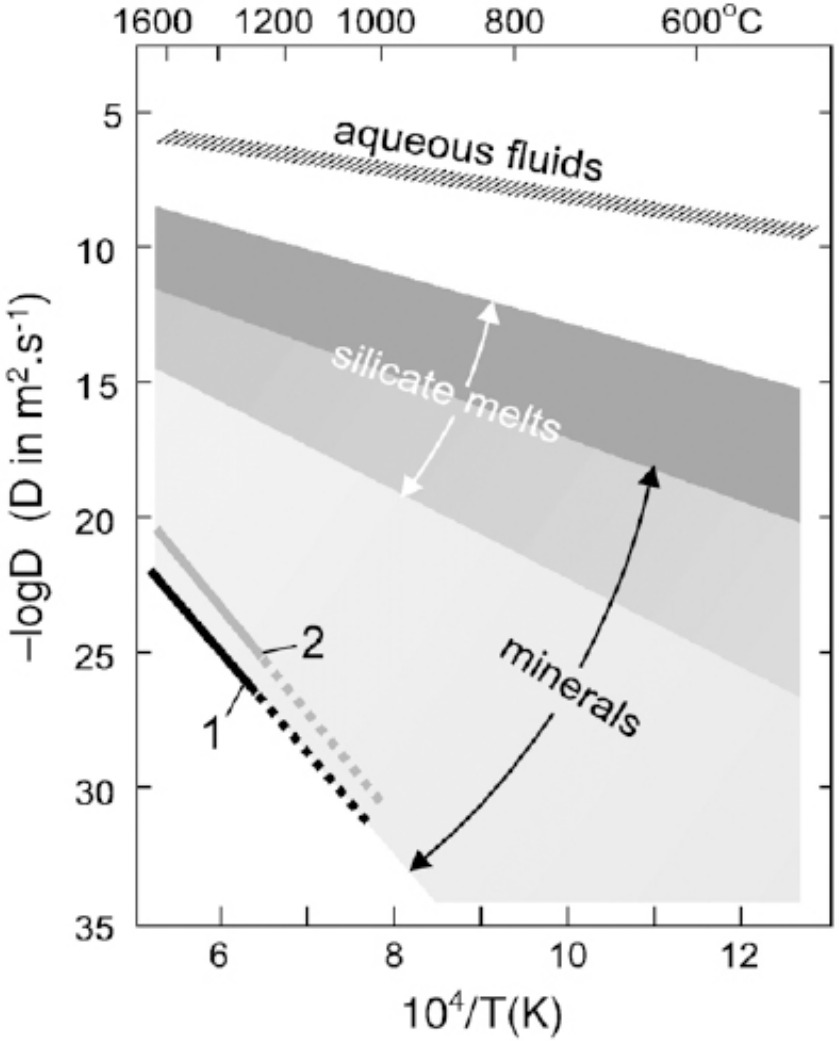


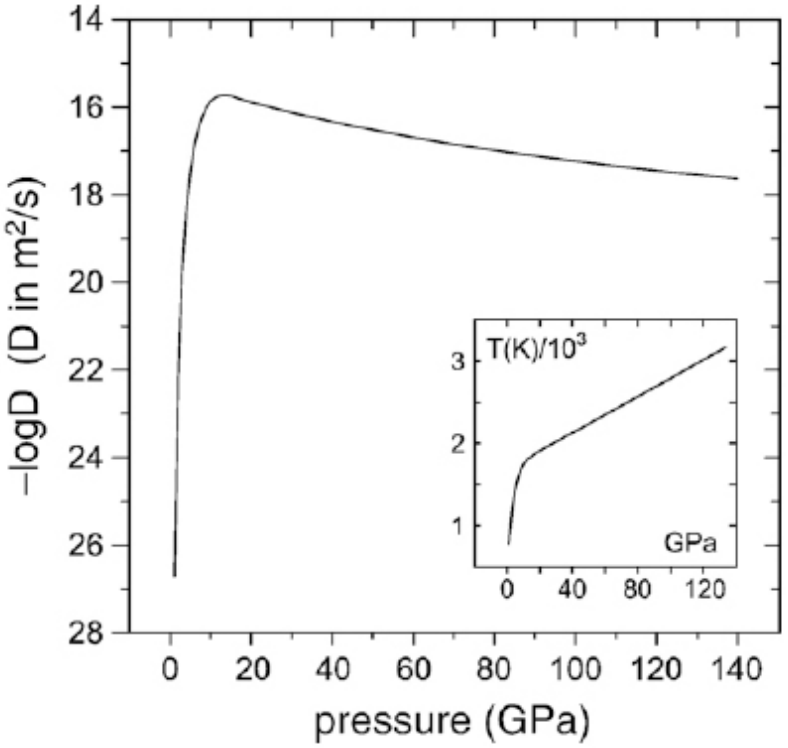
Chakraborty 08

Diffusivity of Earth Materials

T effect $D_i = D_{o,i}\exp(-E_a/RT)$

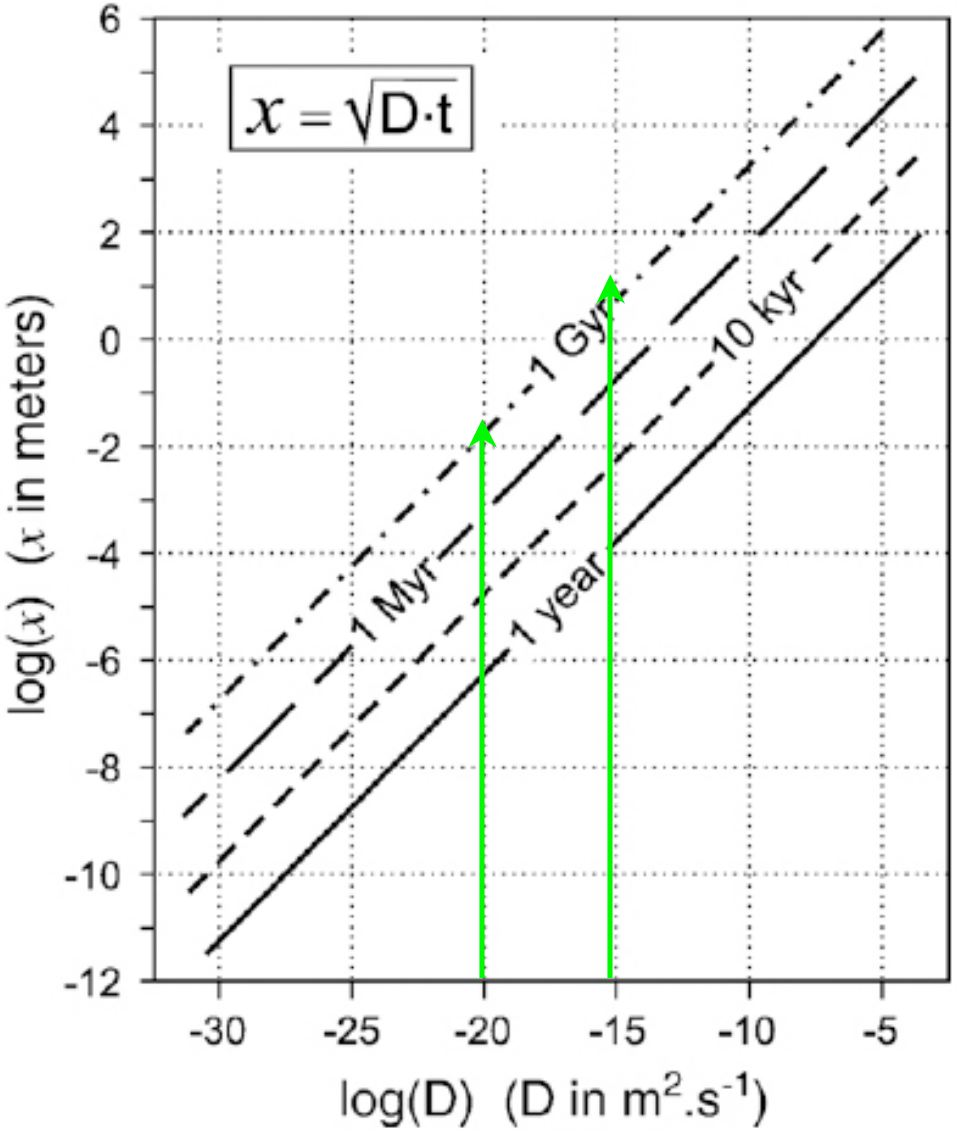
P effect $D_{T,P} = D_T\exp(-PV_a/RT)$



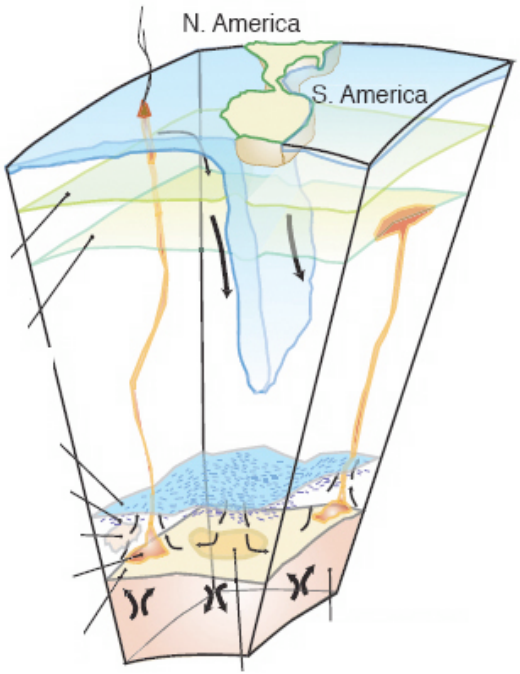


Watson & Baxter 07

Diffusion Length Scale



Mantle



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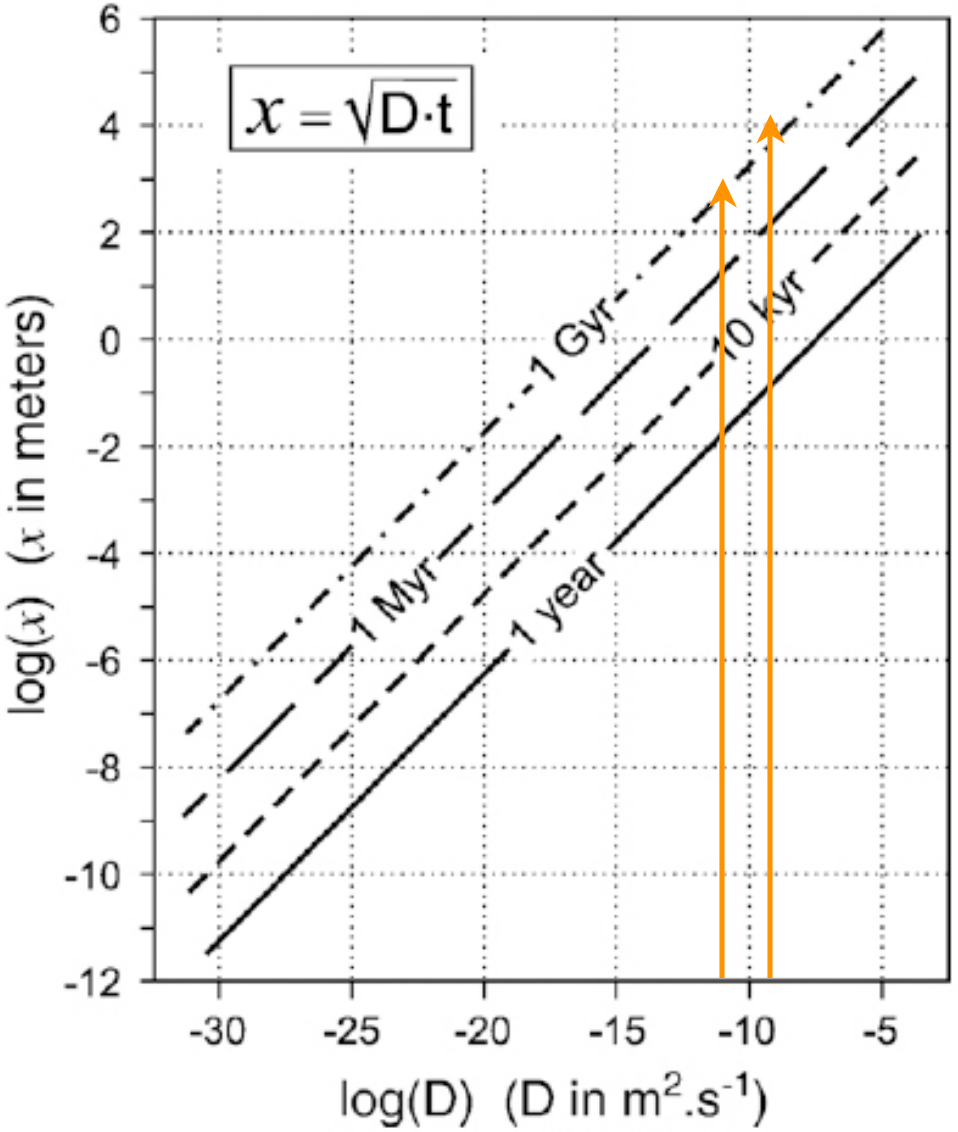
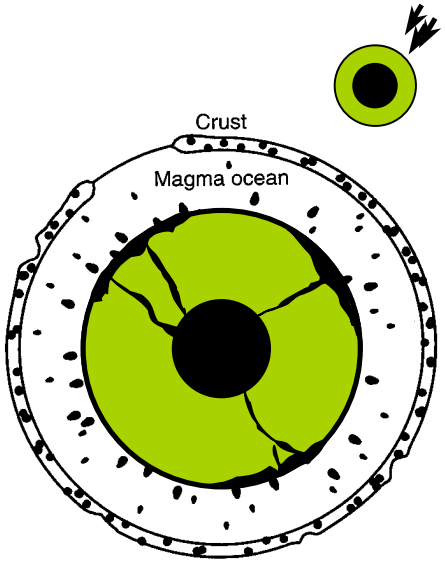
Diffusion Length Scale



Core



Watson & Baxter 07

Conclusions

Diffusion is much slower through crystal lattice than grain boundaries

Diffusion length scale in solid mantle is cm to m over 4.5 Ga

Diffusion length scale in the core maybe 100 m to 10 km over 4.5 GPa, or m to 100 m over 1 Ma