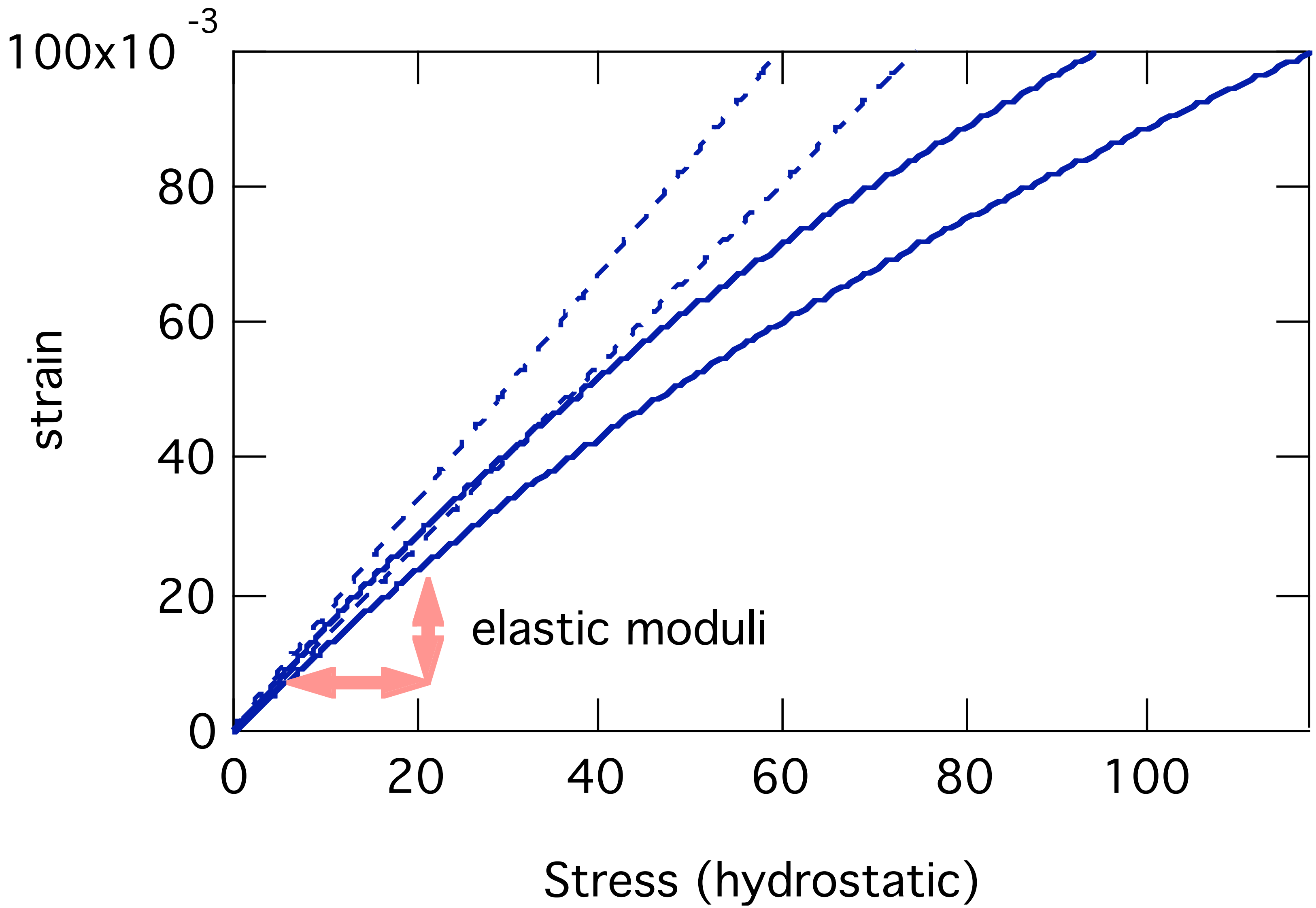
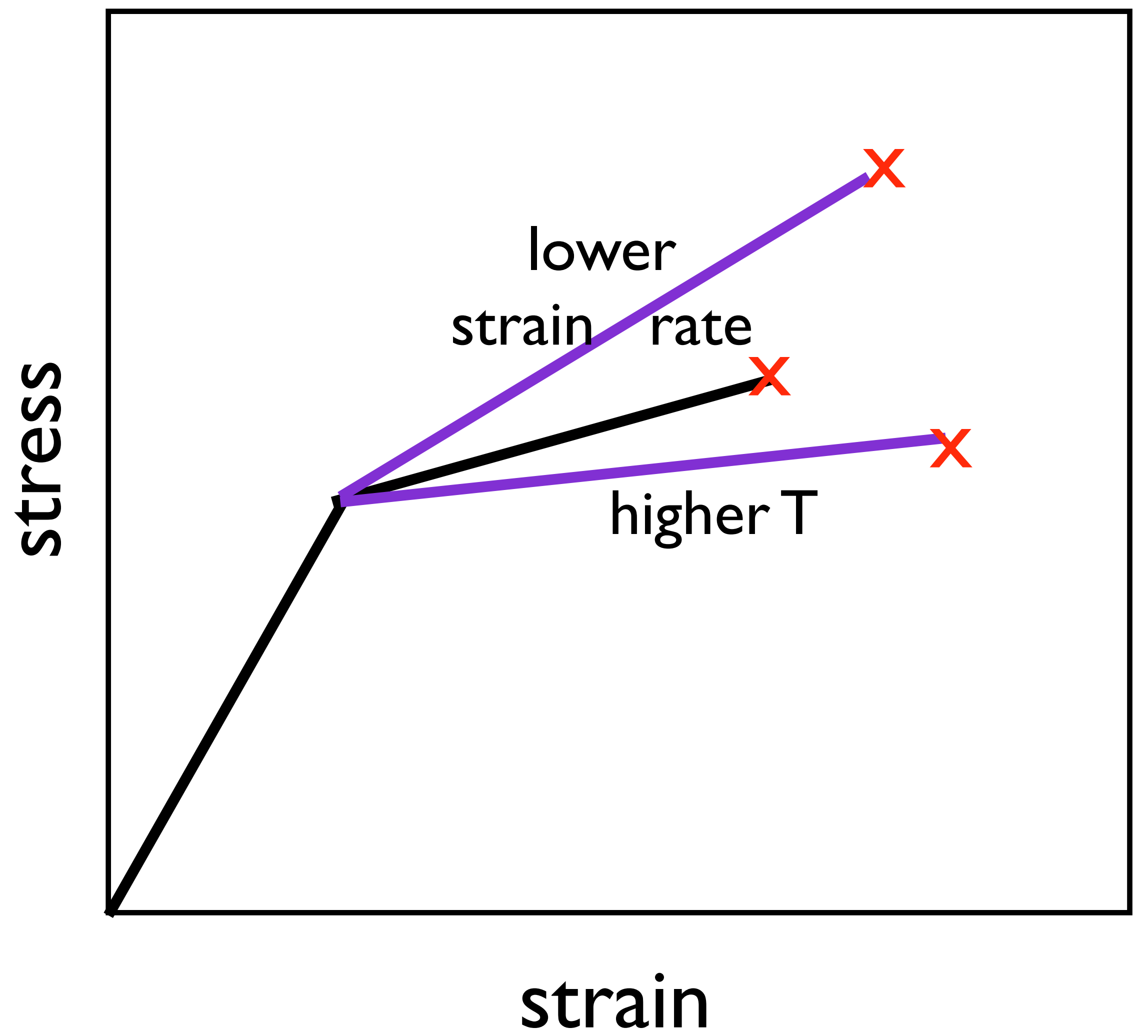
anelasticity and rheology

1. definitions of strength
2. line defects and dislocations
2. activated processes
3. point defects and diffusion
5. planar defects and grain boundary behavior
6. deformation maps

elastic behavior



material "strength" definitions



yield strength	maximum elastic stress before plastic behavior
hardness	amount of plastic deformation for given load
toughness	amount of energy to propagate a fracture

rheology of office supplies

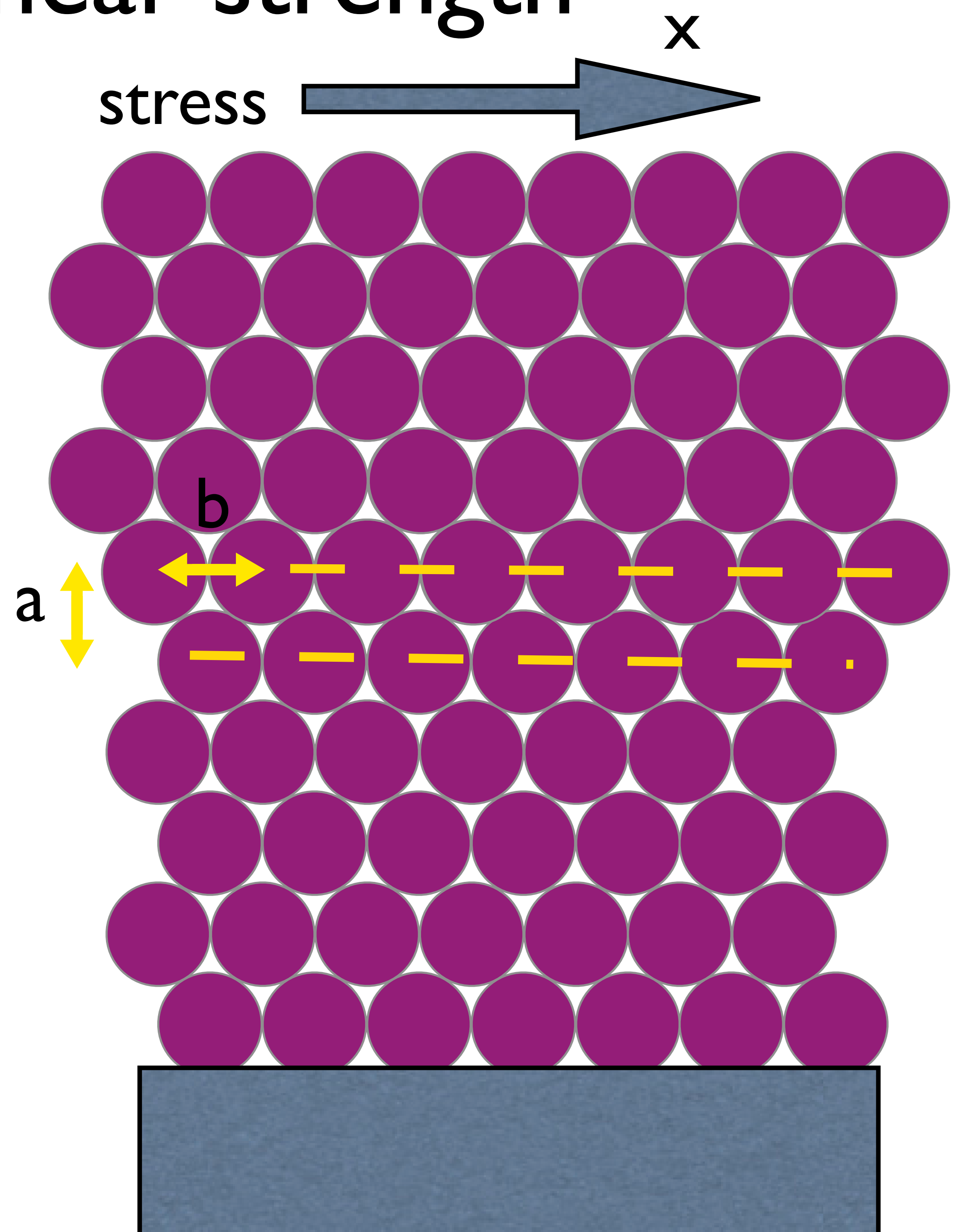
elastic deformation
plastic deformation
work hardening
fracture

theoretical shear strength

i. $t = Gx/a$
ii. $t = c\sin(2\pi x/b)$
iii. $t = \sin(2\pi x/b)Gb/2\pi a$

critical shear stress
is at maximum t:

$t_c \sim G/2\pi$



Predicted

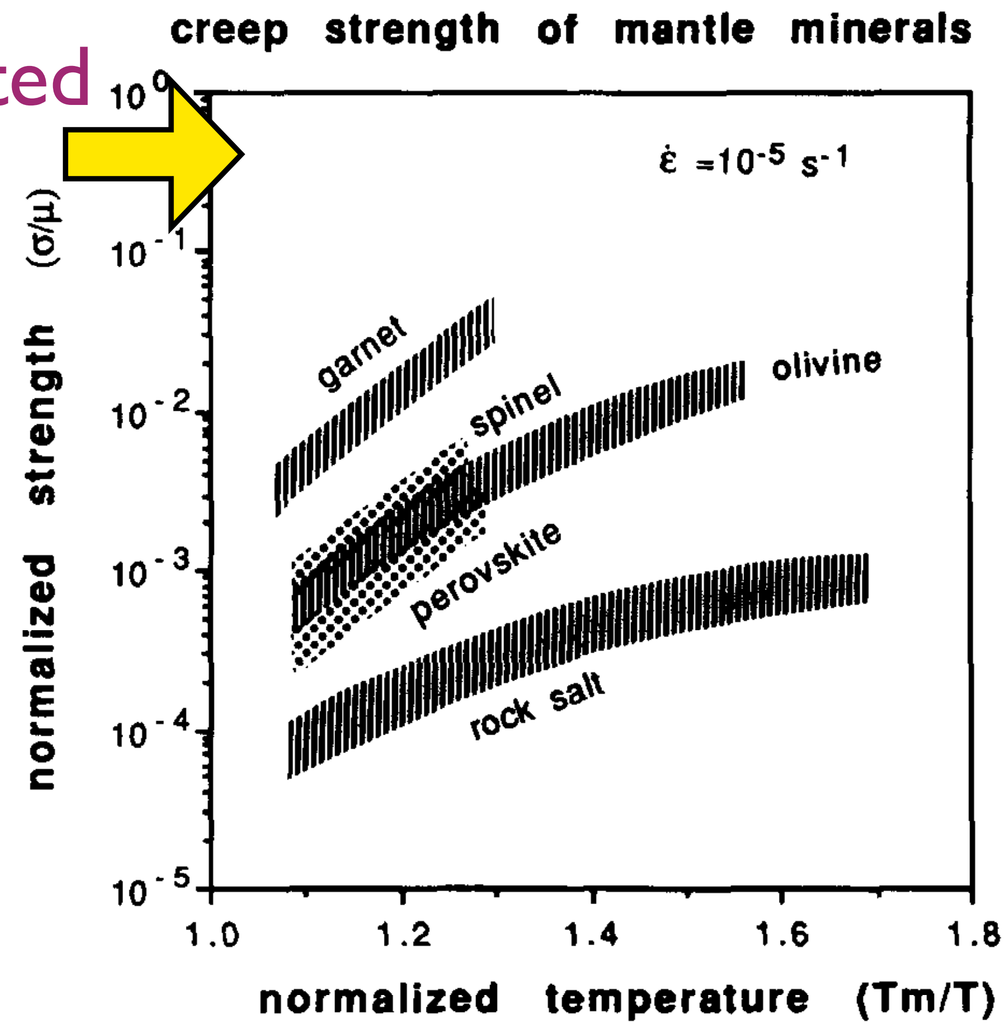


Fig. 3. Strength of typical mantle minerals (for dislocation creep) compared at the same normalized conditions. For anisotropic minerals such as olivine or perovskite, the strength of the hard slip system(s) is shown in this diagram. The strength of a polycrystalline aggregate is well represented by that of the hard slip system(s) [27] and the systematics work better for the hard slip system(s) than the soft ones [21].

Observations:

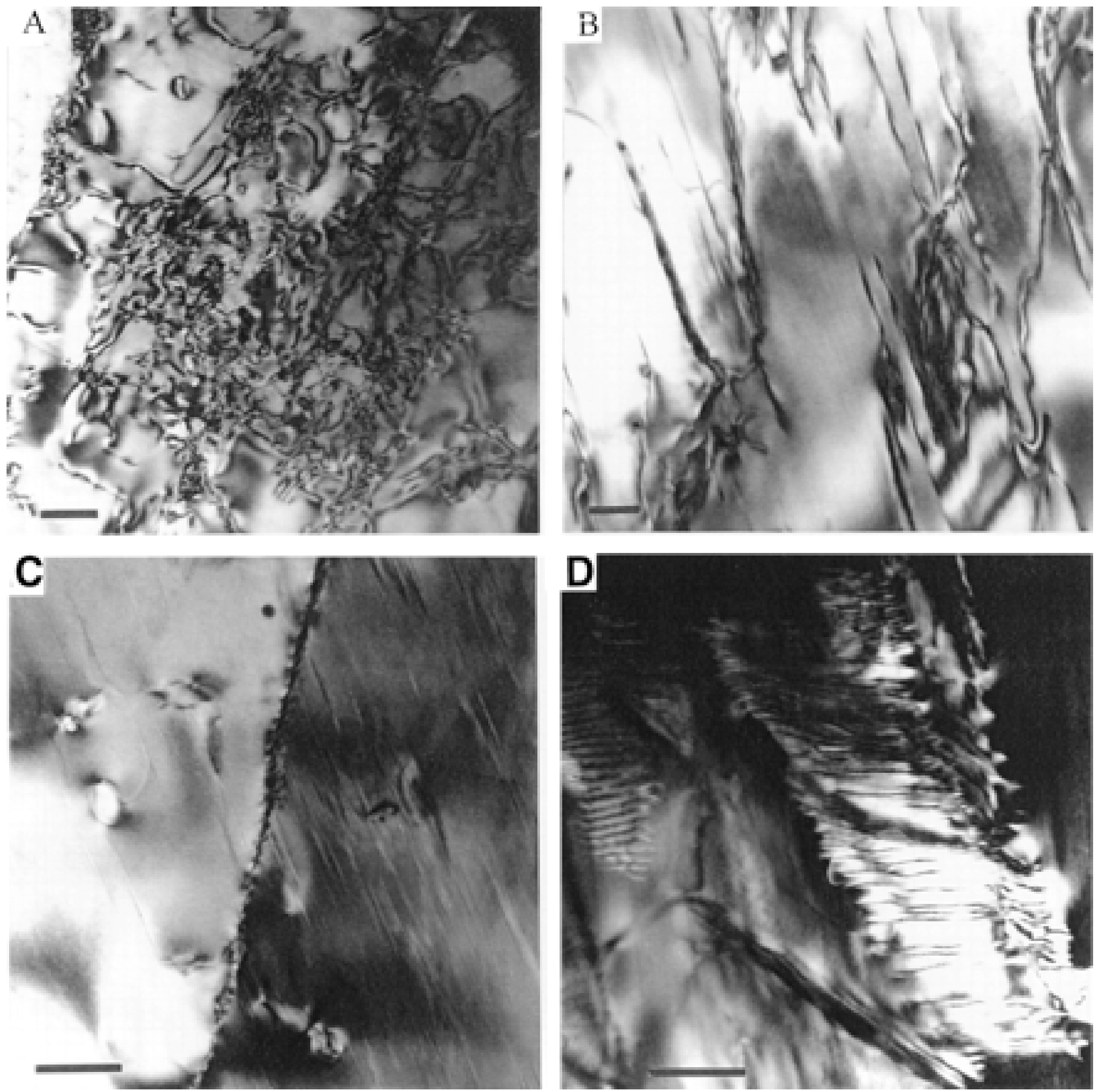
materials fail at much lower stress

=defect control

dislocations in mantle materials

dry

wet



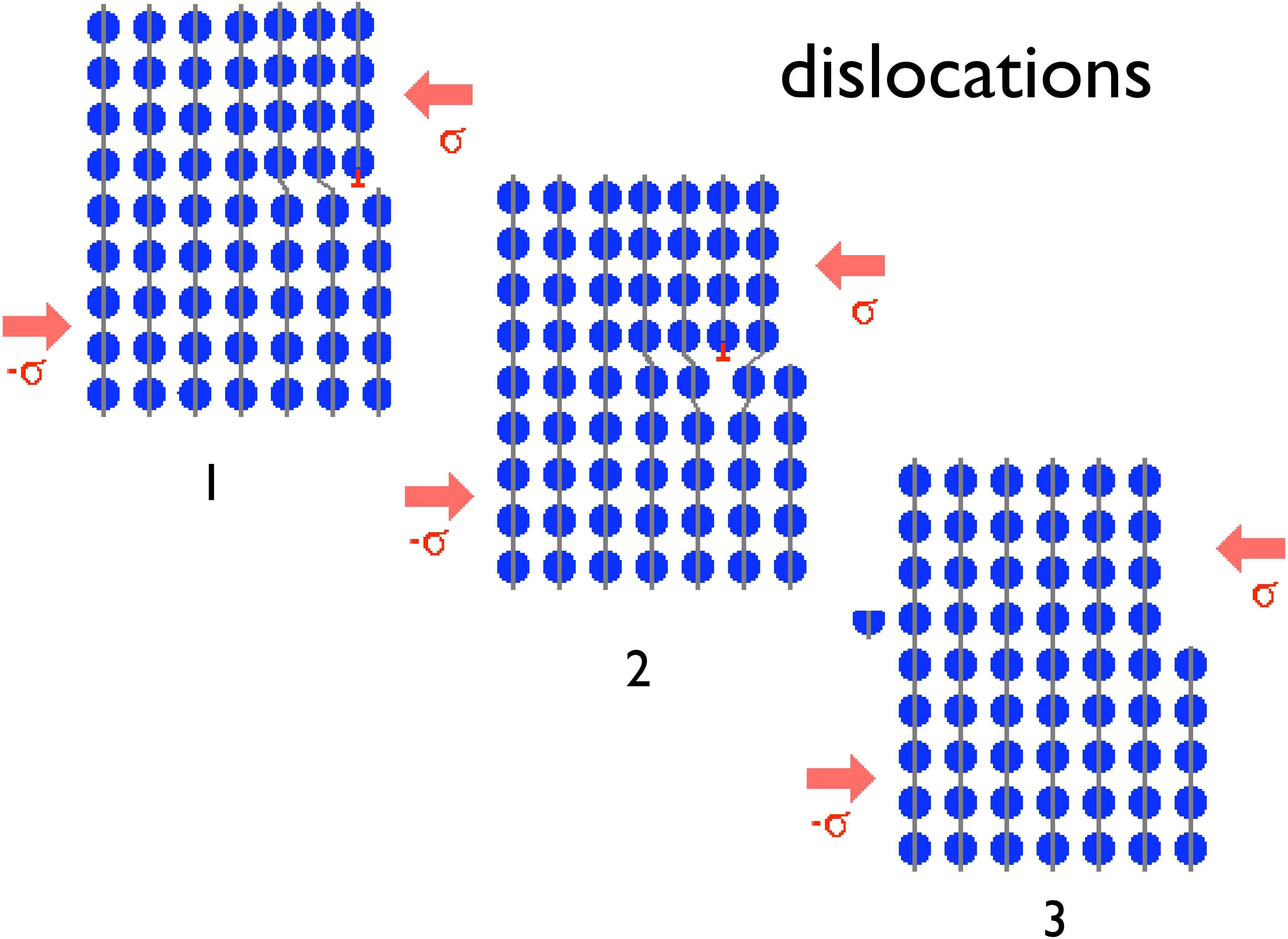
Wadsleyite
Mg2SiO4

TEM
Kubo et al.
1998

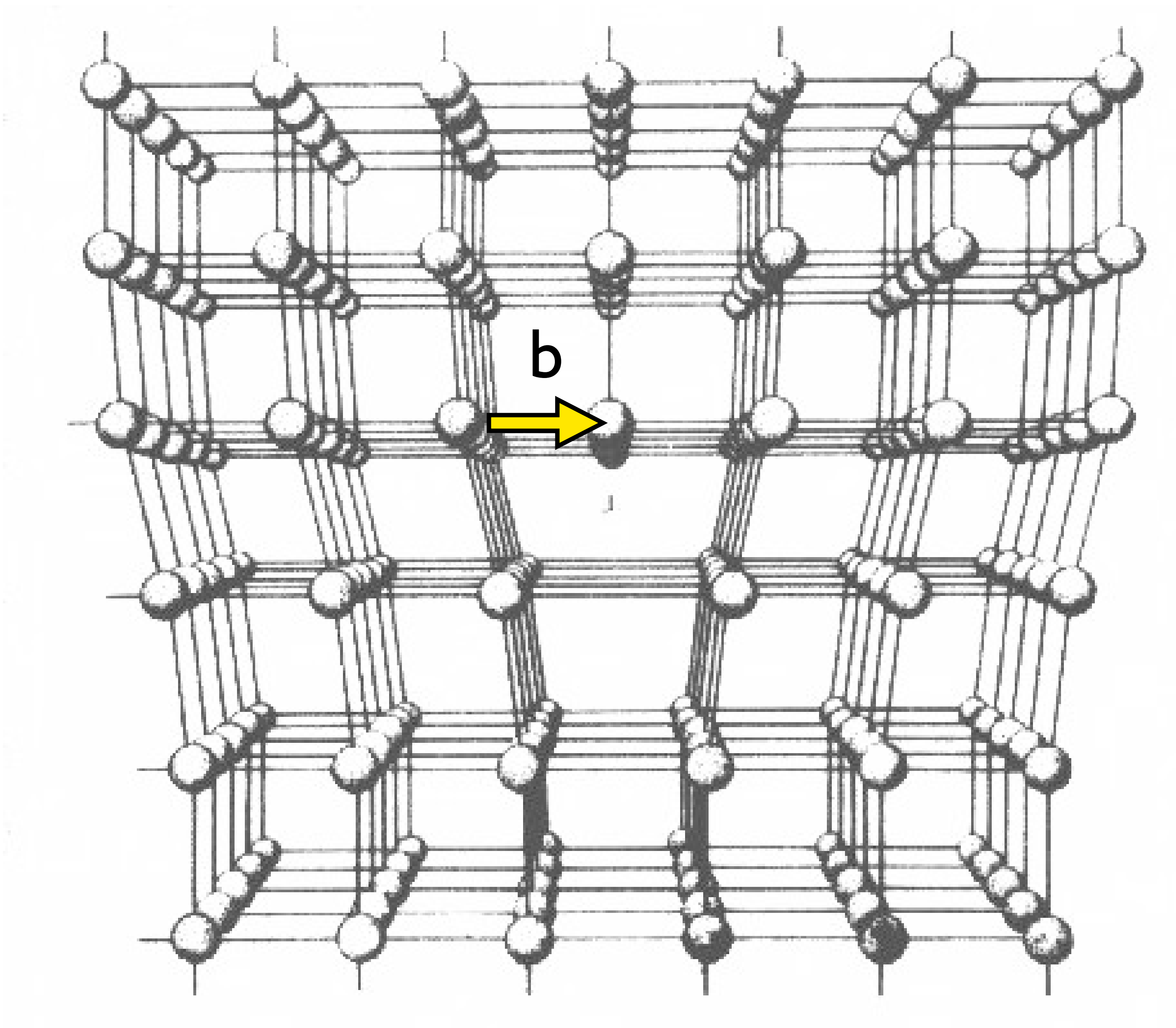
rheology of office supplies II

dislocation motion
rotational component

dislocations

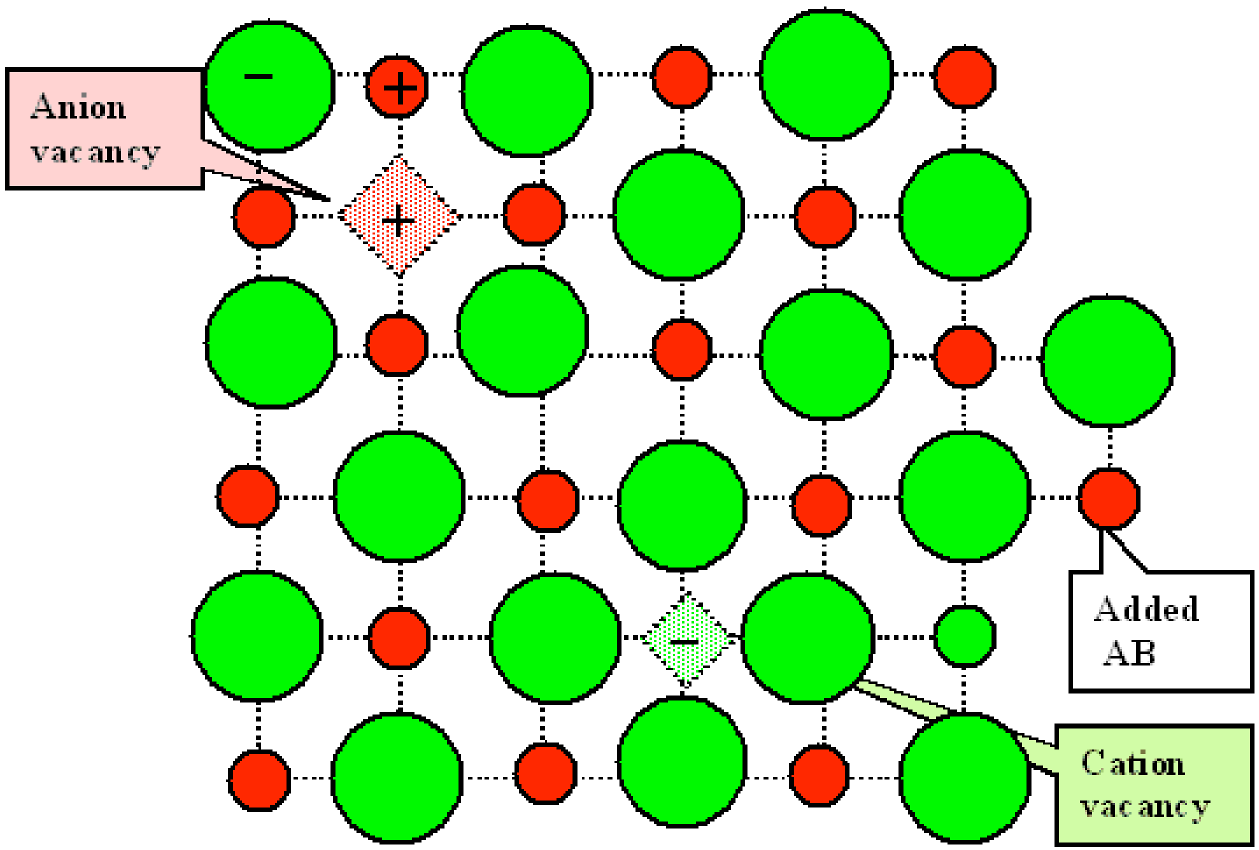


defects--1-di



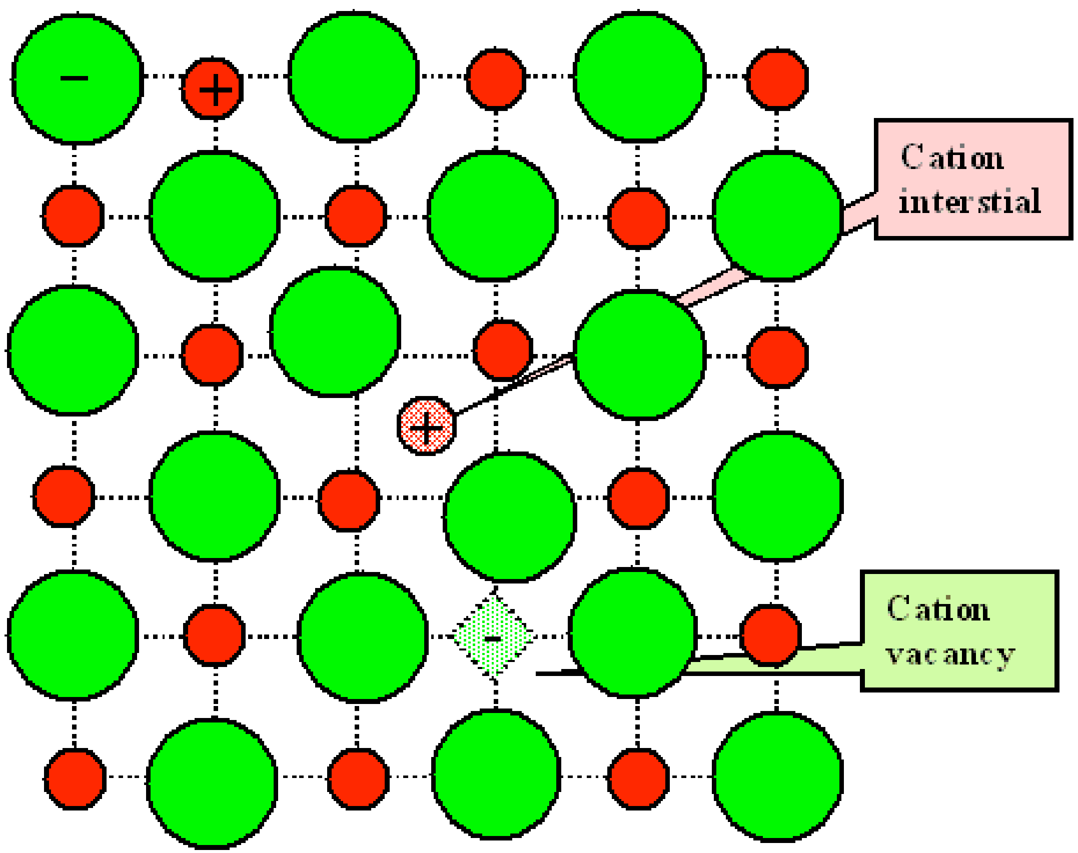
stress field=
Gb/r

defects in materials
--0 dimensional



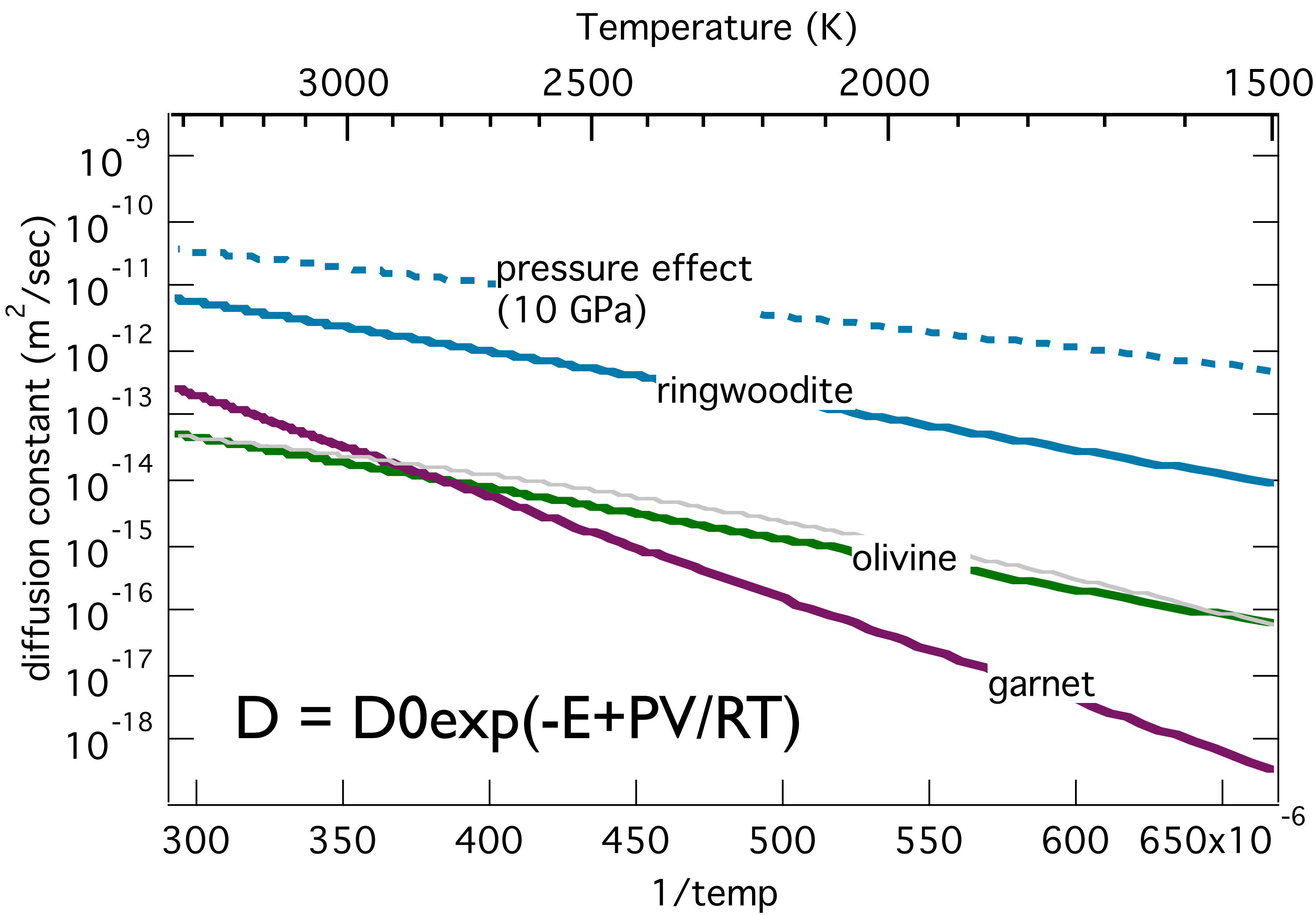
types of point defects:
vacancy
interstitial
substitutional

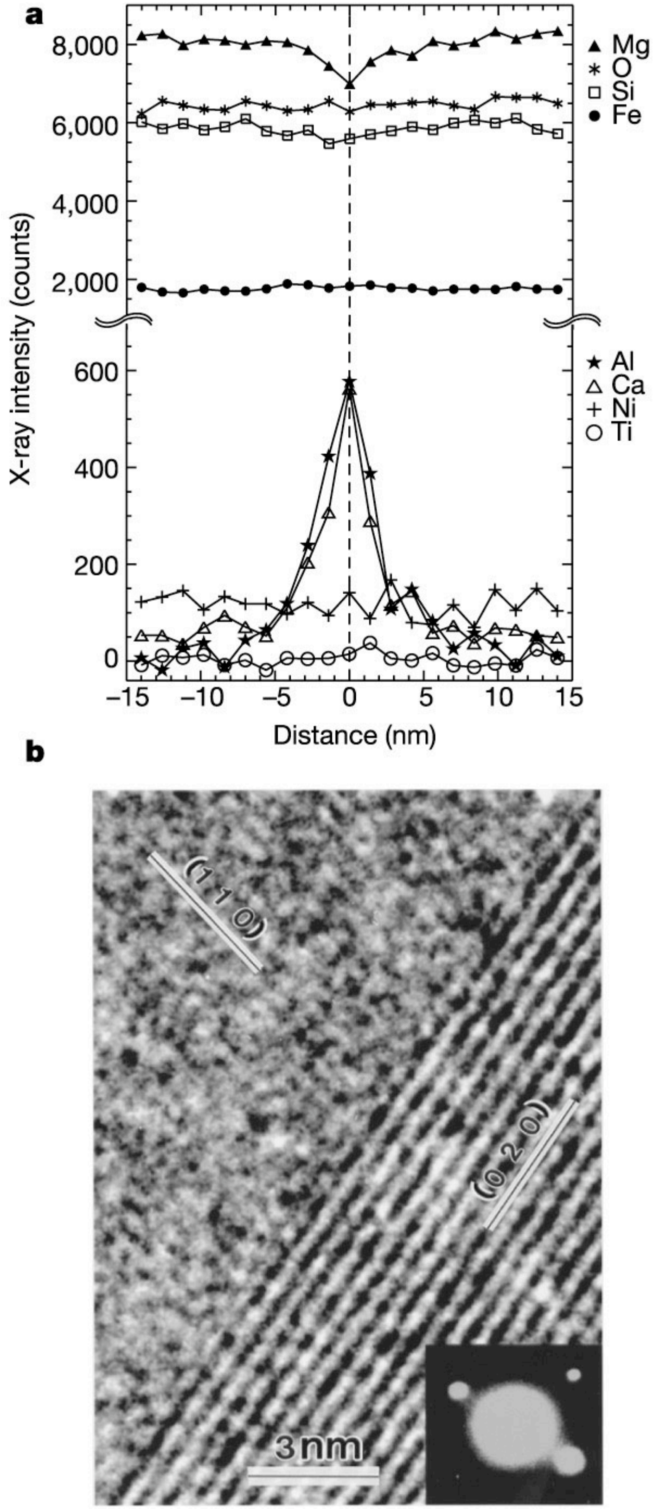
more point defects



constraints on point defects:
charge neutrality
thermodynamics

energetics for diffusion





grain boundaries

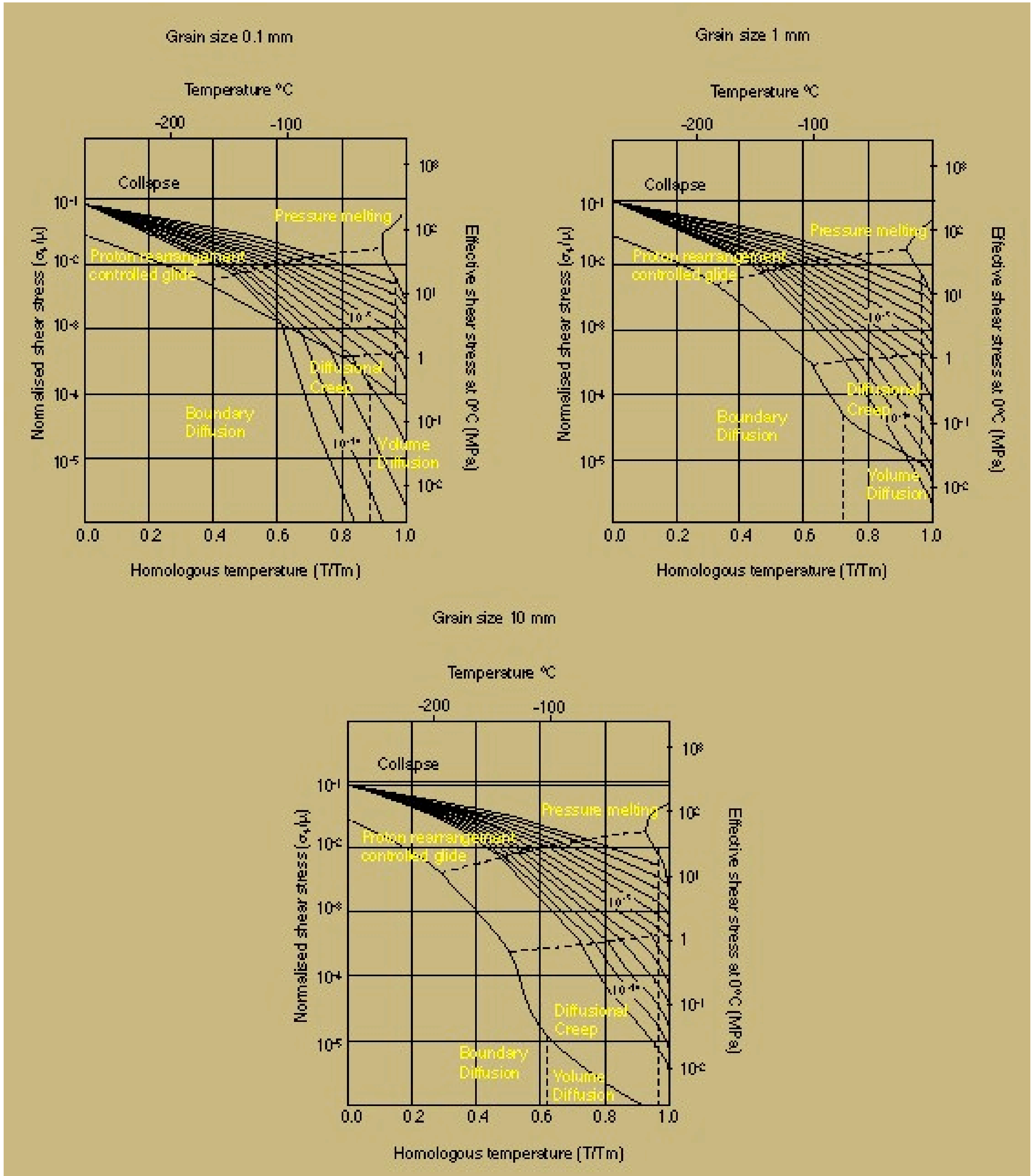
Hiraga, Anderson, Kolstedt
Nature, 2004
"grain boundaries as reservoirs for incompatible elements in the mantle"

creep mechanisms

defect control	name	stress/ strain rate	grain size	temperature	causes LPO?
Diffusion	Nabarro-Herring	independent	independent	strong dependence	no
Dislocation glide	Power-law	strongly dependent	independent	weak dependence	yes
Dislocation climb		less dependent		strong dependence	no
Grain Boundary	Coble creep (superplastic)	independent	strongly dependent	strong dependence	no

lower mantle viscosity

laboratory, seismic waves



deformation maps (ice)

complications:

1. dynamic recrystallization
2. effect of water
3. strain rate extrapolation