METAMORPHIC STRESS

Reading:
Winter Chapter 21, p. 412-417

Stress and Strain

- Stress is an applied force acting on a rock (over a particular cross-sectional area)
- Deviatoric stress affects the textures and structures, but not the equilibrium mineral assemblage
- Strain is the response of the rock to an applied stress (= yielding or deformation)
- Strain energy may overcome kinetic barriers and facilitate reactions

Strain

- **Strain is the response to stress**
- **e is the symbol for strain**
- **$e = \lim \Delta l/l_o$ as Δl approaches zero**
  - **Δl is the change in length in a line element**
  - **l_0 is the original length of the same line element**

Strain Measurements

- **Units of strain are given as a fraction of the initial dimension**
- **Length strain**
  - $e_l = \Delta l/l_o$
- **Volume strain**
  - $e_v = \Delta V/V_o$

Stress

- **Stress is F/A (force/area)**
- **Units are Newtons/m^2, MPa, bars, etc.**
- **σ is the symbol for stress**
- **$\sigma = \lim \Delta F/\Delta A$ as ΔA becomes infinitely small**

Hydrostatic and Lithostatic Pressure

- Lithostatic (and hydrostatic) pressure is uniform stress is all directions
- For hydrostatic pressure, compared with deviatoric conditions, all three components of stress are equal

Directed Stress

- **Tectonism produces non-uniform stress**
- **This causes:**
  - **Rock deformation**
  - **Preferred orientation of mineral grains**
  - **Development of large-scale structures**

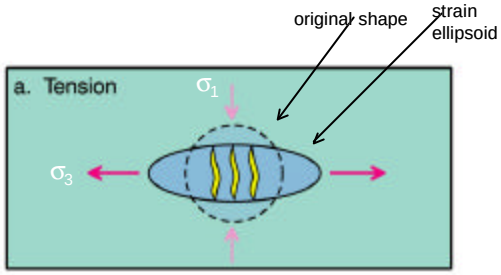
Deviatoric Stress

- Deviatoric stress = unequal pressure in different directions
- Deviatoric stress can be resolved into three mutually perpendicular stress (σ) components:
  - σ_1 is the maximum principal stress
  - σ_2 is an intermediate principal stress
  - σ_3 is the minimum principal stress

Types of Deviatoric Stresses:

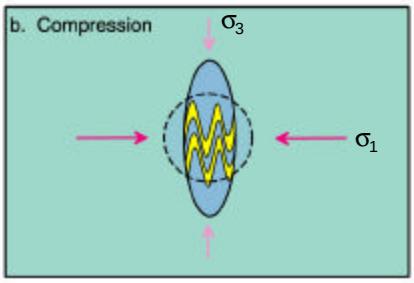
- Tension
- Compression
- Shear

In tension: σ_3 is negative, and the resulting strain is extension, or pulling apart



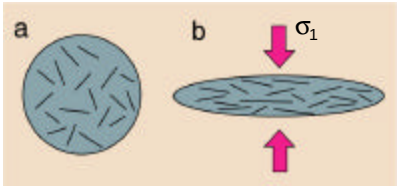
Three types of deviatoric stress with an example of possible resulting structures. a. Tension, in which one stress in negative. "Tension fractures" may open normal to the extension direction and become filled with mineral precipitates. Winter (2001)

In compression σ_1 is dominant: folding produces more homogenous flattening



The three main types of deviatoric stress with an example of resulting structures. b. Compression, causing flattening or folding. Winter (2001)

Foliation Allows Estimation of the Orientation of S_1

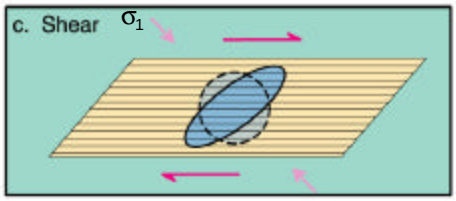


- $\sigma_1 > \sigma_2 = \sigma_3 \rightarrow$ foliation and no lineation
- $\sigma_1 = \sigma_2 > \sigma_3 \rightarrow$ lineation and no foliation
- $\sigma_1 > \sigma_2 > \sigma_3 \rightarrow$ both foliation and lineation

Flattening of a ductile homogeneous sphere (a) with randomly oriented flat disks or flakes. In (b), matrix flows with progressive flattening, and the flakes are rotated toward parallelism normal to the predominant stress. Winter (2001)

Metamorphic Agents and Changes

Shear motion occurs along planes at an angle to σ_1



The three main types of deviatoric stress with an example of possible resulting structures. b. Shear, causing slip along parallel planes and rotation. Winter (2001)

Metamorphic Fluids

Evidence for the existence of a metamorphic fluid:

- Fluid inclusions
- Fluids are required for hydrous or carbonate phases
- Volatile-involving reactions occur at temperatures and pressures that require finite fluid pressures

Fluid Pressure

- P_{fluid} indicates the total fluid pressure, which is the sum of the partial pressures of each component ($P_{fluid} = p_{H2O} + p_{CO2} + \ldots$)
- May also consider the mole fractions of the components, which must sum to 1.0 ($X_{H2O} + X_{CO2} + \ldots = 1.0$)

Spatial Variations

- Gradients in T, P, X_{fluid} across an area
- Zonation in the mineral assemblages