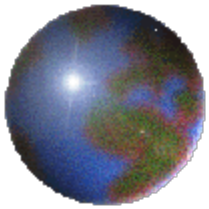


4 Pre-mining state of stress

Topic 1 Factors influencing the state of stress

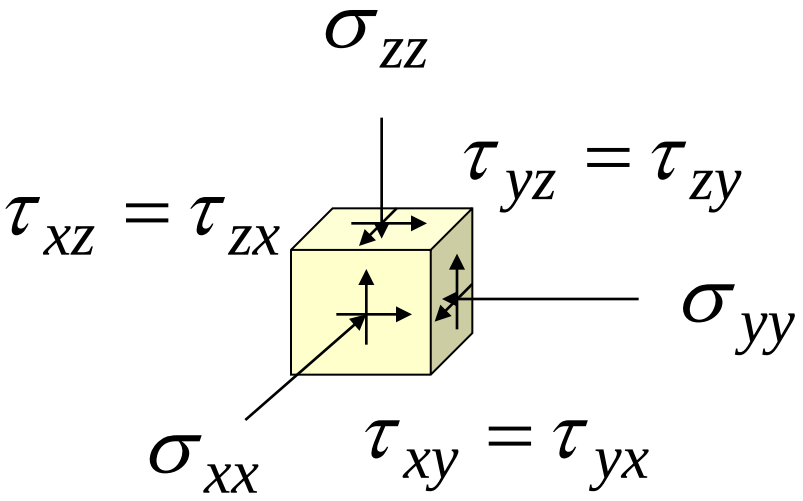
Topic 2 In-situ stress measurement

International Journal of Rock Mechanics & Mining Sciences 40 (2003) 955
Special Issue on Rock Stress Estimation

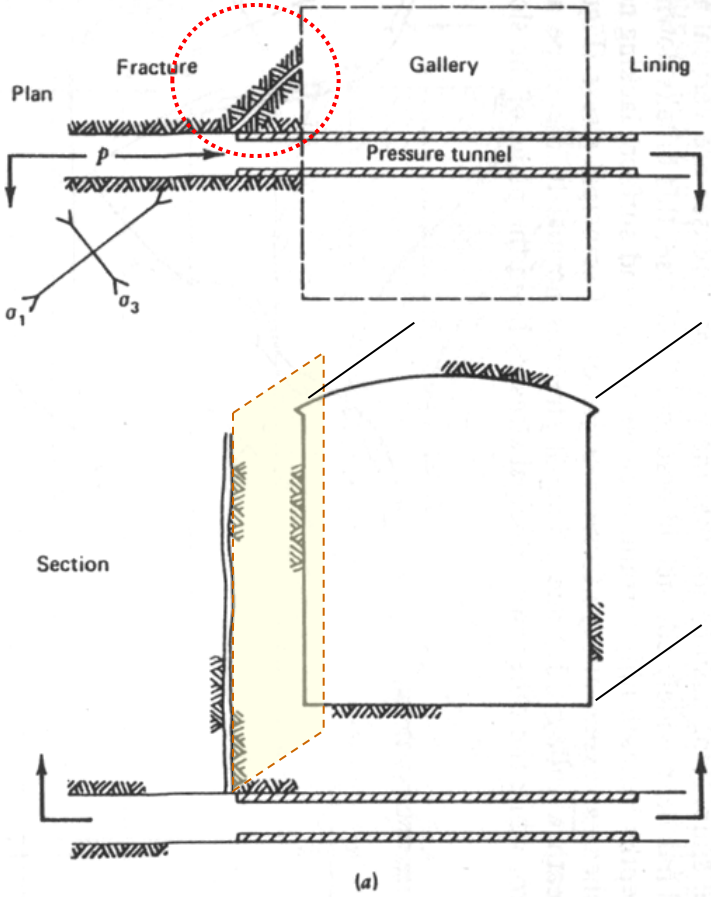
What is stress

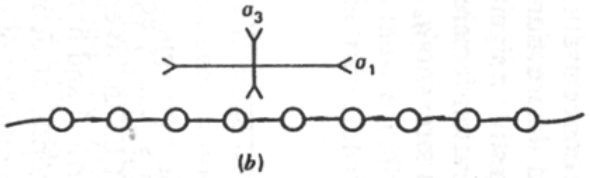
- Force is a vector
- Stress will varied with concerned plane
- Stress is a tensor
  - Defined by three surface tractions (vector) at three orthogonal plane

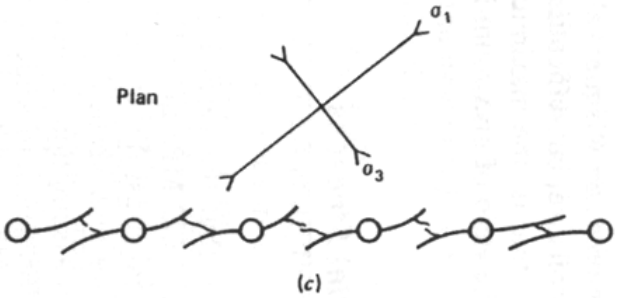
$$\begin{bmatrix} \sigma_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_{zz} \end{bmatrix}$$



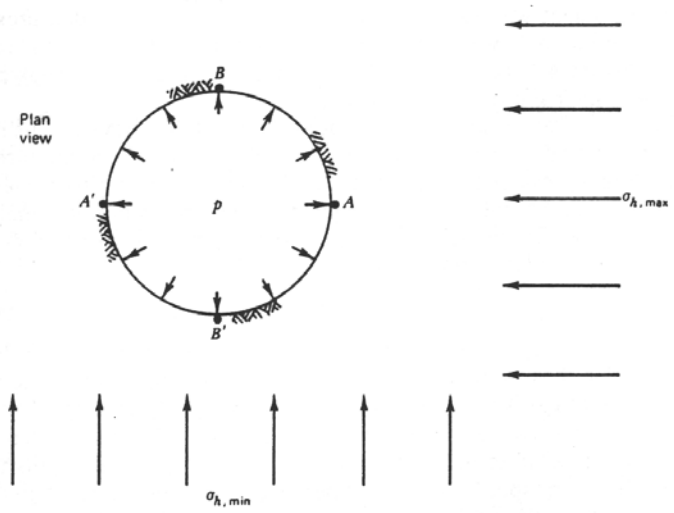
Influence of the initial stresses



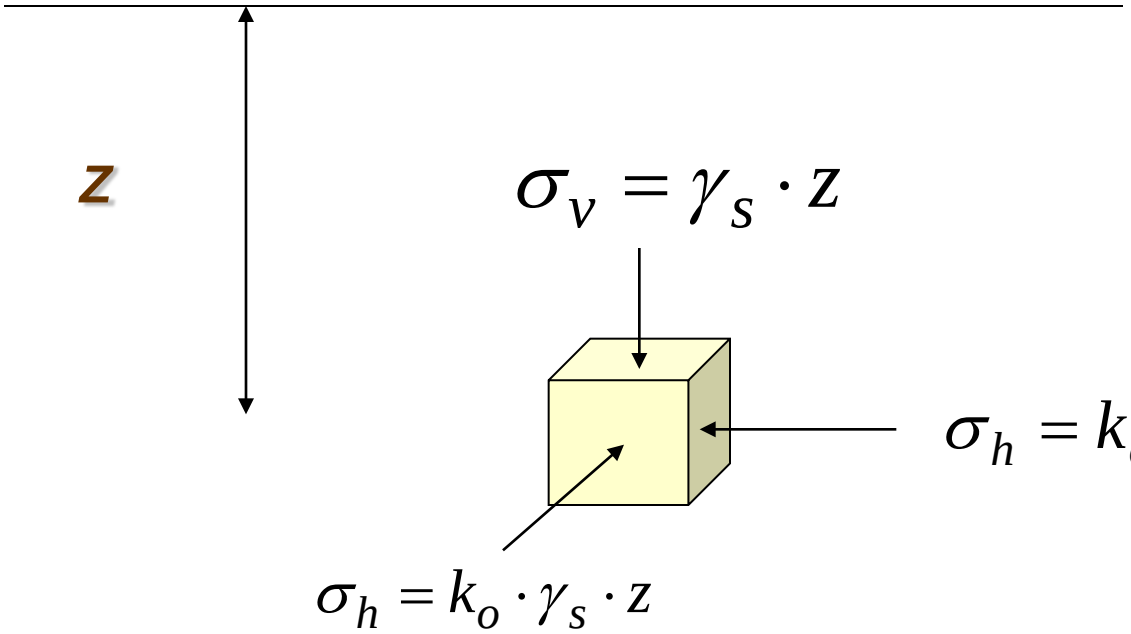




Joint opening
Tunnel lining
Excavation
Rock burst …



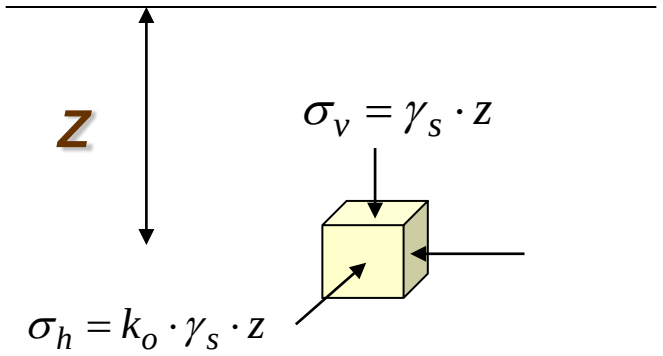
Stress at subsurface (gravitational stress)



Ko = ?

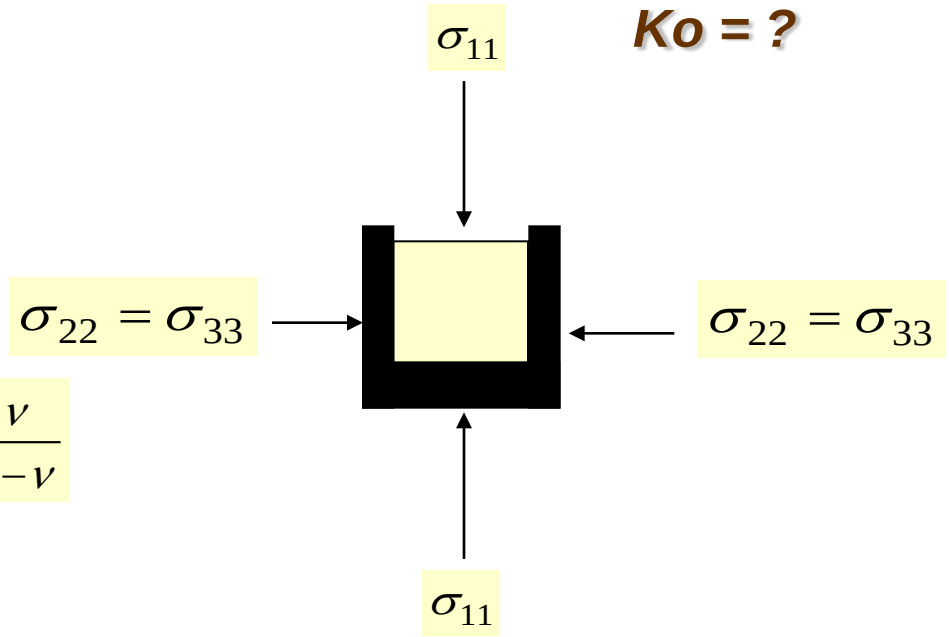
Linear-elastic, isotropic materials

$$\begin{bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{23} \end{bmatrix} = \begin{bmatrix} \frac{1}{E} & -\frac{\nu}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\ -\frac{\nu}{E} & \frac{1}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\ -\frac{\nu}{E} & -\frac{\nu}{E} & \frac{1}{E} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G} \end{bmatrix} \times \begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \tau_{12} \\ \tau_{13} \\ \tau_{23} \end{bmatrix}$$



Lateral Confined Loading (oedometer)

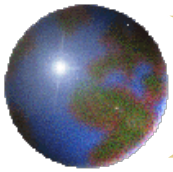
Ko = ?



$$\varepsilon_{22} = -\frac{\nu}{E}\sigma_{11} + \frac{1}{E}\sigma_{22} - \frac{\nu}{E}\sigma_{33} = 0$$

$$\sigma_{22} = \sigma_{33} = \frac{\nu}{1-\nu}\sigma_{11} \qquad k_o = \frac{\nu}{1-\nu}$$

if $\nu = 0.4$ $\quad k_o = \frac{\nu}{1-\nu} = 0.67$



z

$\sigma_v = \gamma_s \cdot z$

$\sigma_h = k_o \cdot \gamma_s \cdot z$

$\sigma_h = k_o \cdot \gamma_s \cdot z$

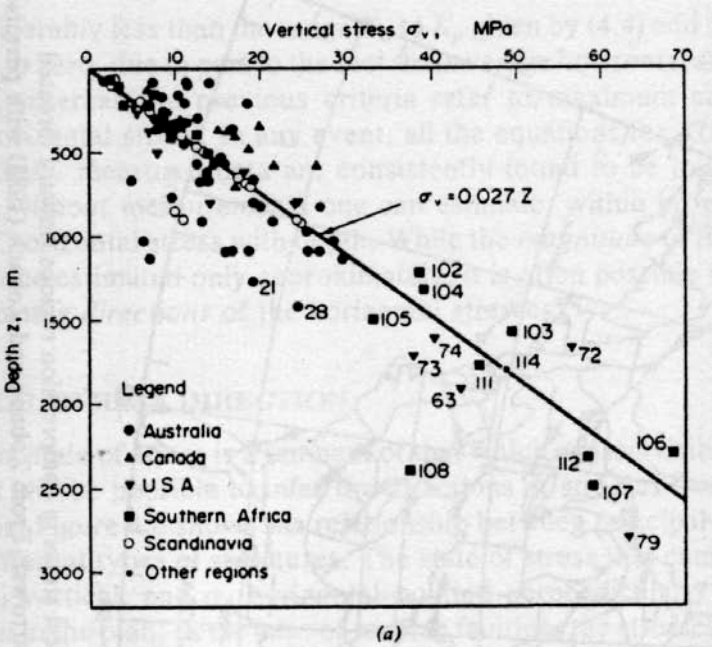
$\sigma_v = \gamma_s \cdot z$

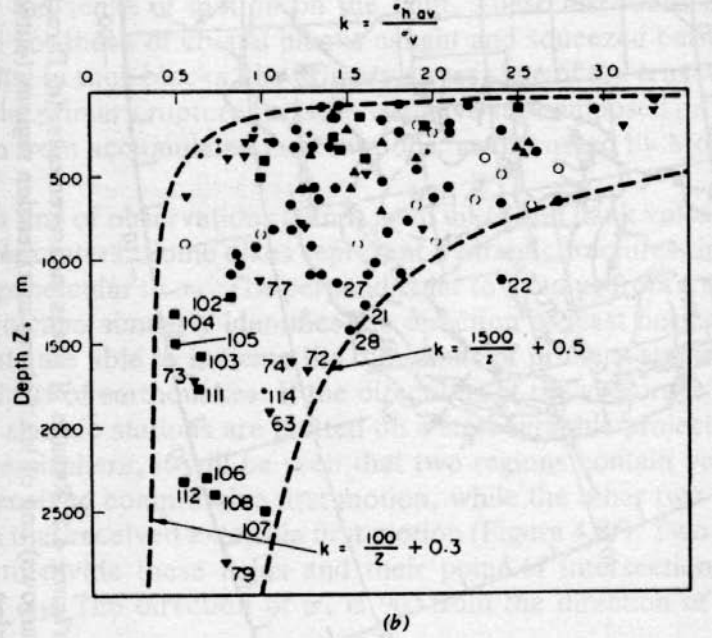
$k_o (= \frac{\sigma_h}{\sigma_v})$

z

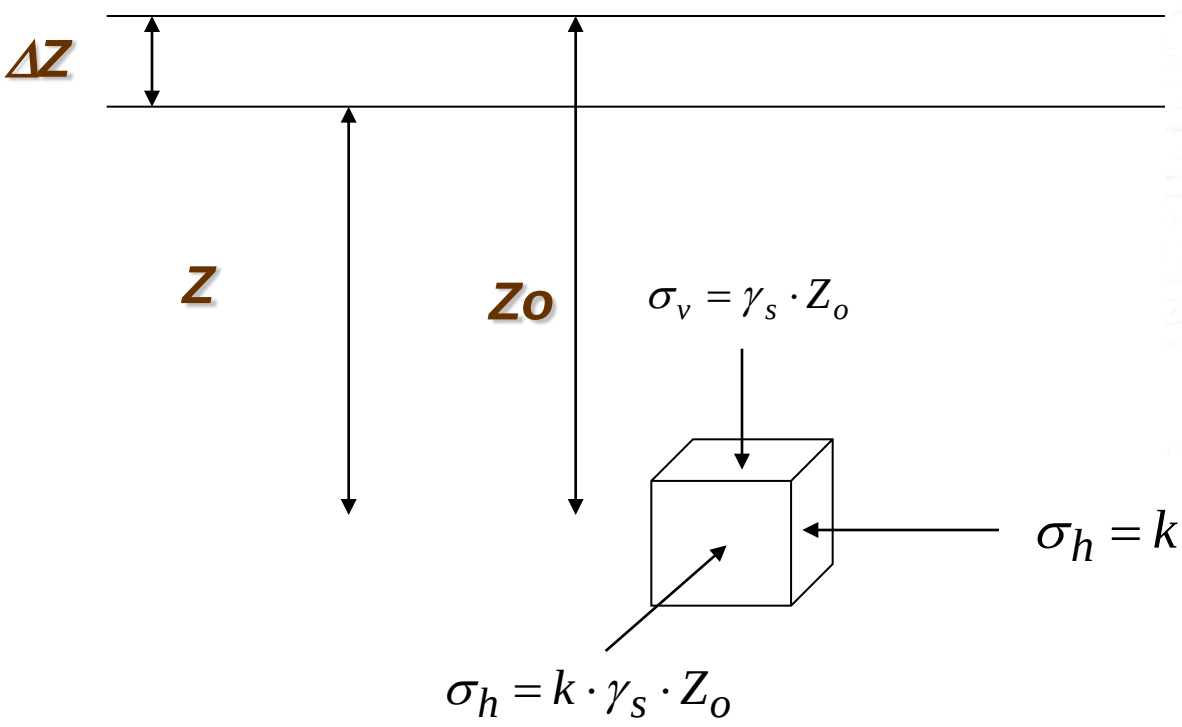
if $\nu = 0.4$ $k_o = \frac{\nu}{1-\nu} = 0.67$

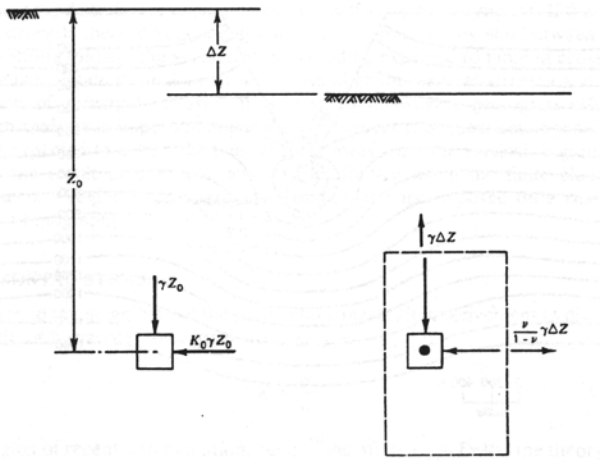
Why?





Effect of erosion





$$\Delta\sigma_v = \gamma_s \cdot \Delta Z$$

$$\Delta\sigma_h = \left(\frac{\nu}{1-\nu}\right) \cdot \Delta\sigma_v$$

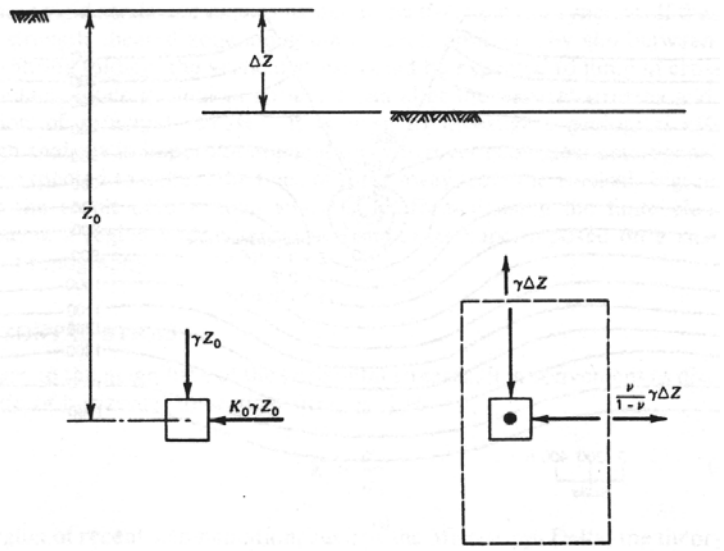
$$K_{erosion} = \frac{\sigma_h - \Delta\sigma_h}{\sigma_v - \Delta\sigma_v} = \frac{k \cdot \gamma_s \cdot Z_o - \left(\frac{\nu}{1-\nu}\right) \cdot \gamma_s \cdot \Delta Z}{\gamma_s \cdot Z_o - \gamma_s \cdot \Delta Z}$$

$$\because Z = Z_o - \Delta Z \qquad \therefore Z_o = Z + \Delta Z$$

$$K_{erosion}(Z) = \frac{k \cdot \gamma_s \cdot (Z + \Delta Z) - \left(\frac{\nu}{1-\nu}\right) \cdot \gamma_s \cdot \Delta Z}{\gamma_s \cdot Z} = k + \left(k - \frac{\nu}{1-\nu}\right) \cdot \frac{\Delta Z}{Z}$$

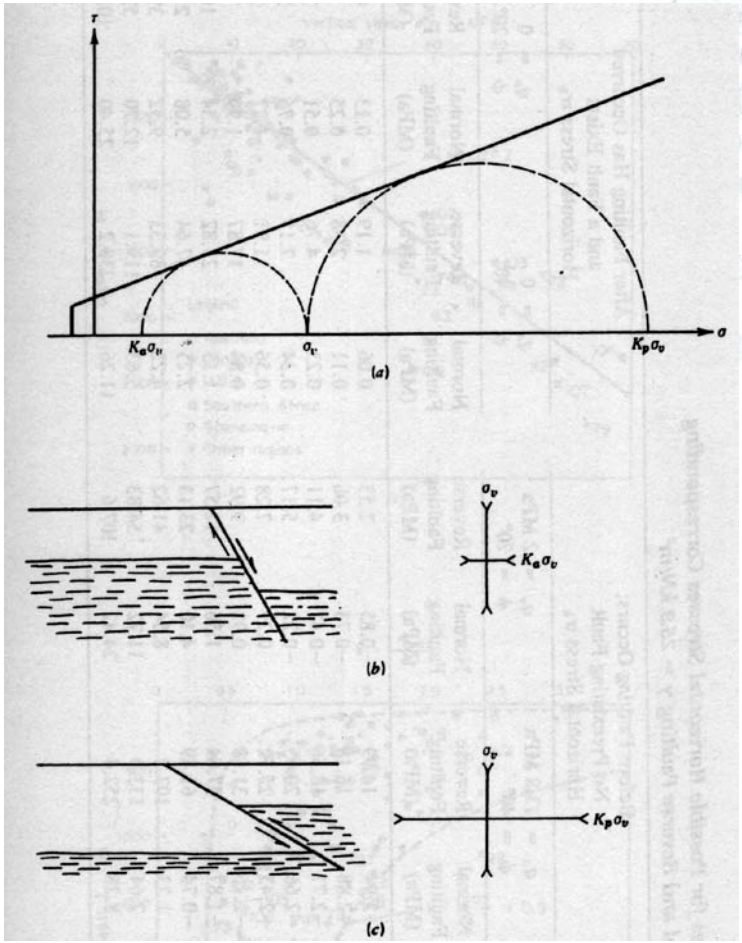
HW1

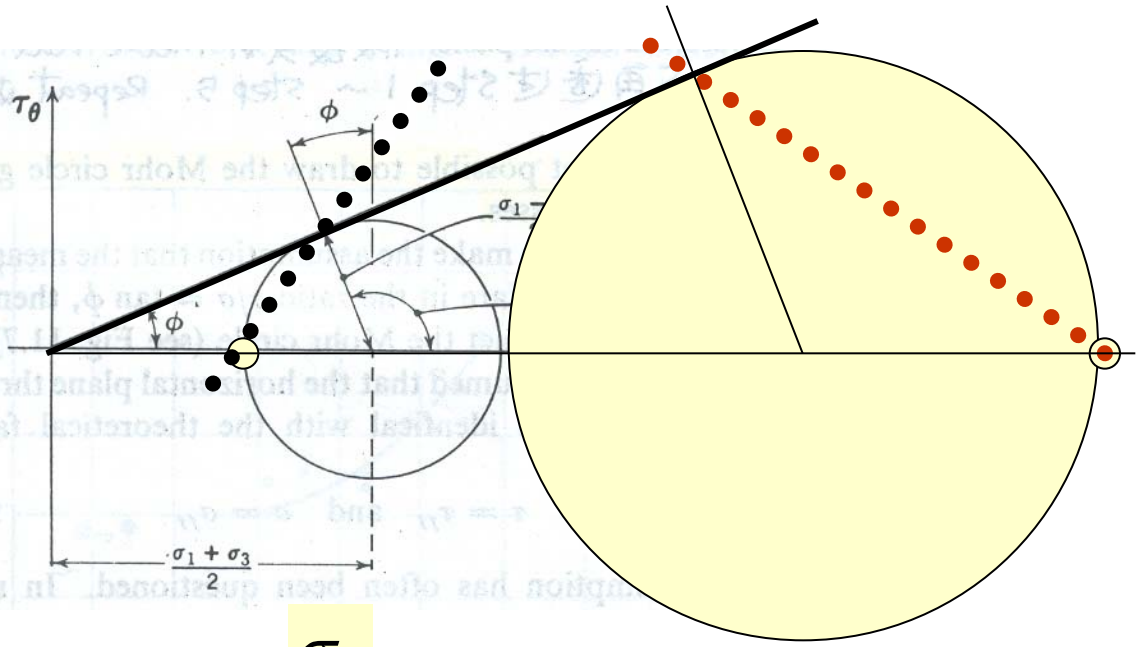
- 某處地層沉積過程中原始靜止土壓力係數為0.8，伯松比為0.3，該處有20公尺的地層遭侵蝕作用而消失，請繪出該處現在靜止土壓力係數與深度之關係圖。

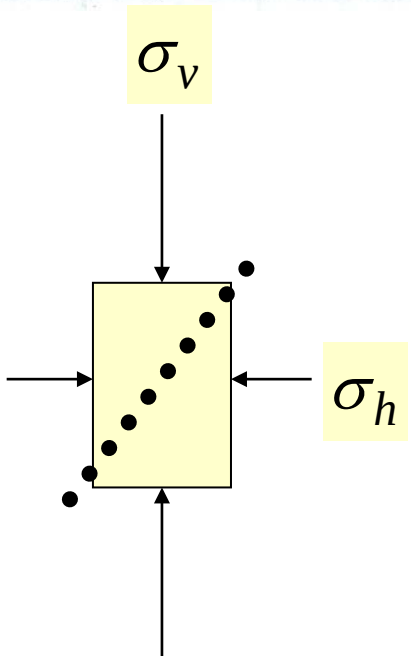


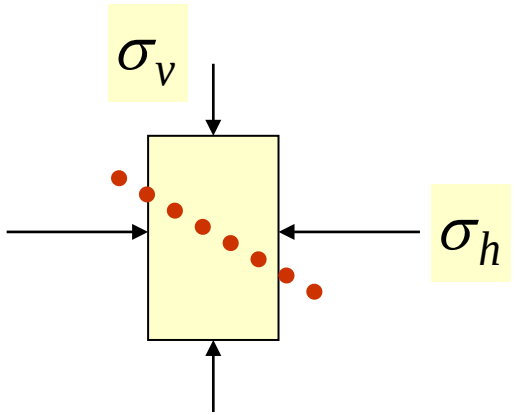
Upper bound and lower bound of ratio of horizontal to vertical stress

$$K_a < K_o < K_p$$









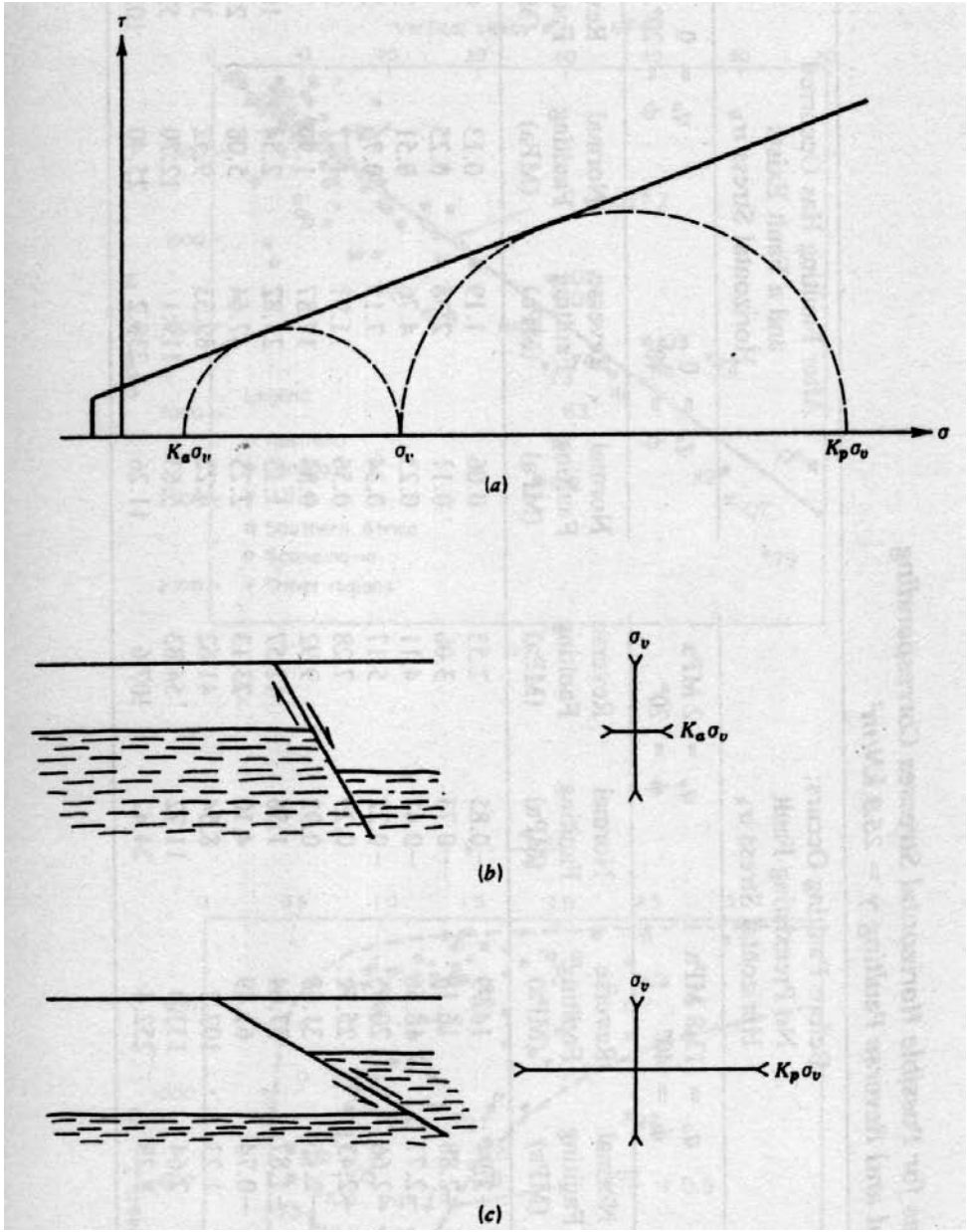
HW2

- Prove

$$K_a = \frac{\gamma_s \cdot Z - q_u}{\gamma_s \cdot Z \cdot \tan^2(45^o + \phi/2)}$$

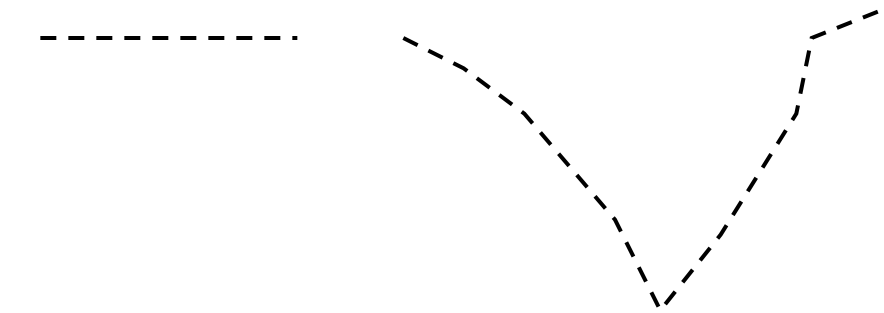
$$K_p = \tan^2(45^o + \phi/2) + \frac{q_u}{\gamma_s \cdot Z}$$

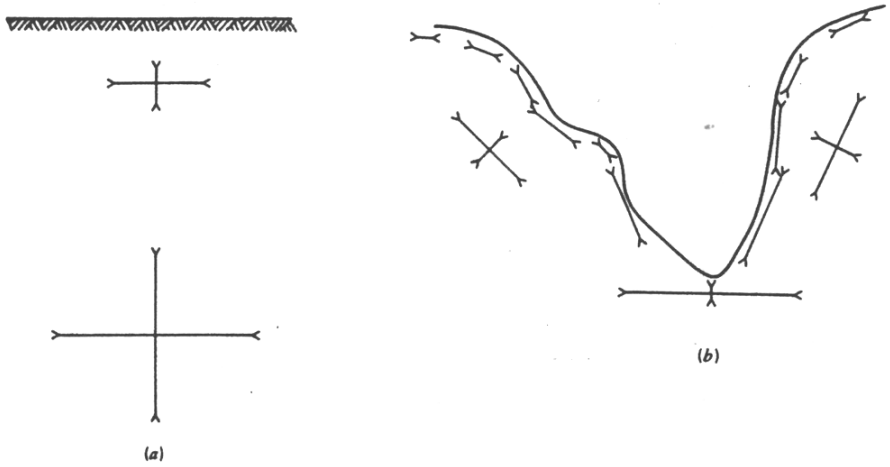
- If q_u=1MPa, ϕ=30^o γ_s=2.5 T/m^3, please find the upper and lower bound of Ko when z=1km, 2km, and 3km

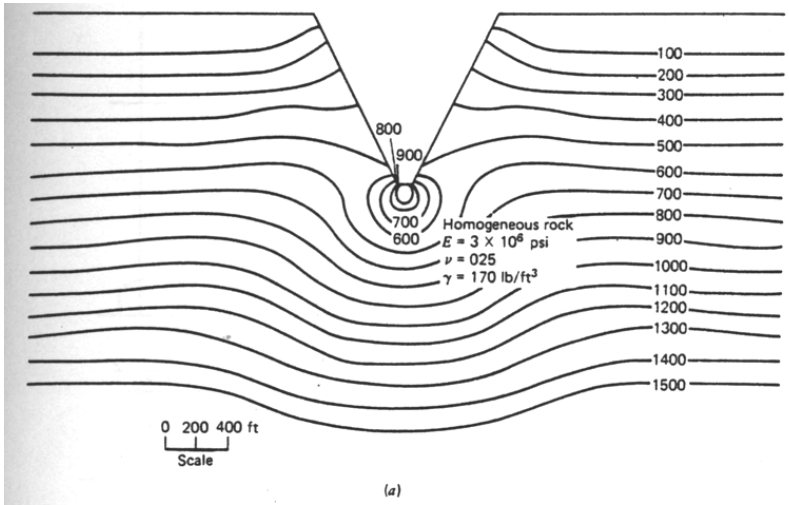


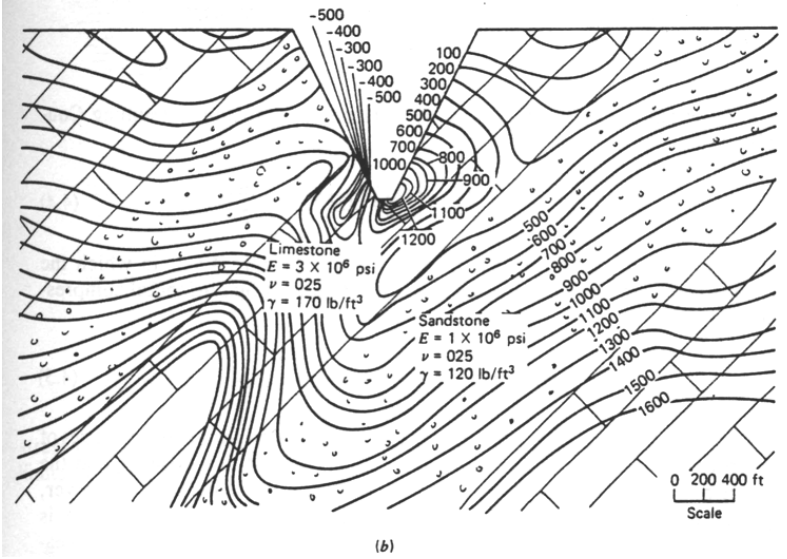
Surface topography

Stress?

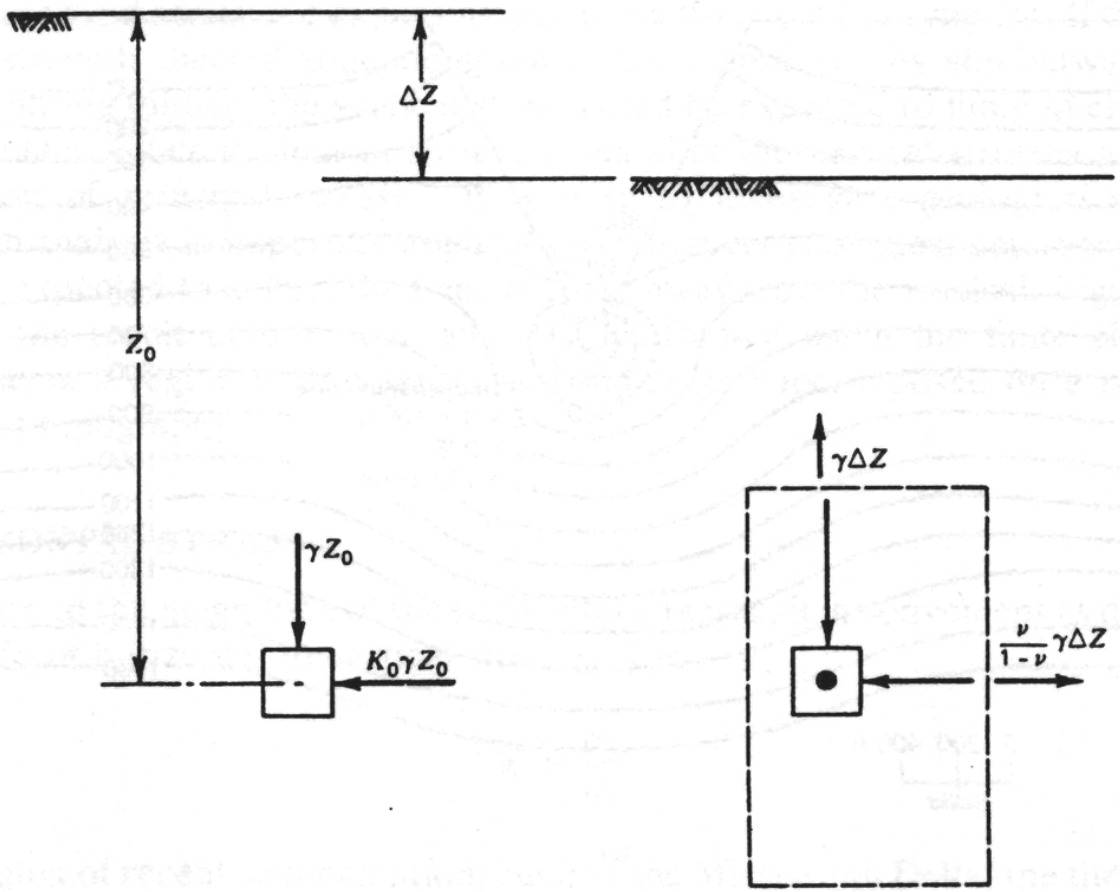








Surface erosion



Residual stress

- **Cast-iron body on cooling** (Timoshenko and Goodier, 1970)
  - **Exterior cooling more rapidly than the interior**
- **Locally lock-in stress**
  - **Non-uniform cooling**
  - **different coefficients of thermal expansion**
  - **Mineralogical changes**
  - **Local recrystallisation**
  - **Changes in water content**
    - **Chemically or physically**

Inclusions

- Extrusive features
  - Dykes , sills, and veins
- Emplaced high pressure
- Different elastic modulus
  - Stiff inclusions induced high stress state

Tectonic stress

- **Thrust faulting and folding**
  - One sub-horizontal stress component significantly greater than both the overburden stress and the other horizontal stress
  - This effect should persist at depth
- **Distinction between erosion effect**
  - Erosion – shallow depth