Bedrock Channels and Tectonic Geomorphology, Cont.

Flow types:

Debris flow, lahar (volcanic), mud flow (few gravel, no boulders)

Flowing mixture of water, clay, silt, sand, gravel, boulder, etc.

Flowing is liquefied with about 15% of water by weight.

Rheology: function of grain size distribution.

Mud flow $\rightarrow$ non-newtonian fluid

Wet grain flow $\rightarrow$ friction and collisions with pore pressure

Mud flows:

Visco-plastic (simplification)

$$\tau = \tau_y + \mu \frac{\partial v}{\partial z}$$

$$\frac{\partial v}{\partial z} = \frac{1}{\mu}(\tau - \tau_y)$$

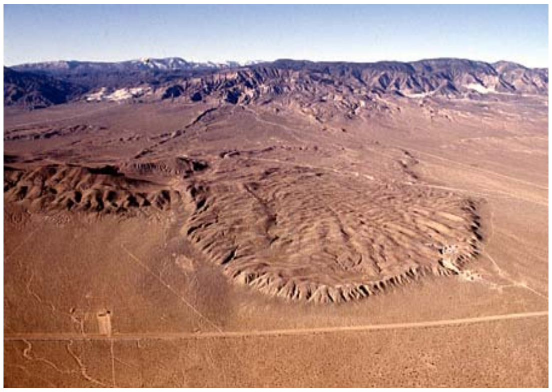
Simplification:

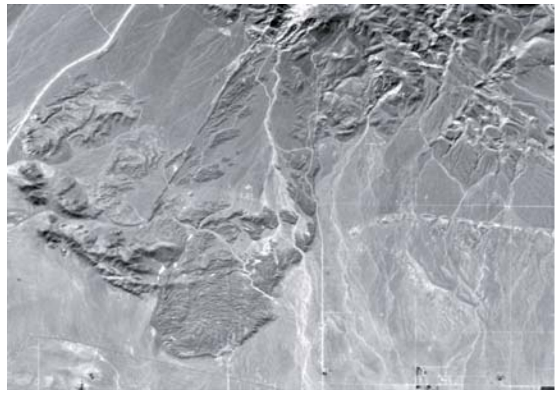
τ_y = constant (f(grain size, H_2O%))

μ = constant (f(grain size, H_2O%))

MOVIE SHOW (made by USGS in 1984)

Debris Flow:





Landslides:

Rock avalanches

Rock fall (toppling of blocks)

Shallow soil landslides (tabular)

Deep bedrock landslides (tabular)

Earth flows (slow oozing $\Rightarrow$ reactivations over long time)

Rotation slumps

Slope stability (initiation of failure)

F $\Rightarrow$ factor of safety

F = 1, at failure (or critical)

F > 1, stable

F < 1, unstable

$$\mathrm{F} = \frac{\text{strength (resisting force)}}{\text{driving force}} = \frac{s_t}{\tau_{b_{wet}}} = \frac{c + (\sigma_{wet} - p)\tan\phi}{\rho_{b_{wet}} ghS}$$

where ϕ is friction angle.

Infinite slope approximation $\Rightarrow$ no end effects

$s_t = c + \sigma \tan\phi_i$ where ϕ_i is internal friction angle.

$s_t = c' + (\sigma - p)\tan\phi$ where c' is total effective cohesion.

$$F_s = \frac{s_t}{\text{driving stress}} \equiv 1 \text{ at failure}$$

$\tau_b = \rho_b gh \sin\alpha$ where ρ_b is wet soil bulk density.

$\rho_b = v_s\rho_s + m(1-v_s)\rho_w$ where v_s is volume fraction solids and *m* is fraction of soil depth saturated.

$\sigma = \rho_b gh \cos\alpha$

$$F_s = \frac{c' + (\sigma - p)\tan\phi}{\tau_b} = \frac{c' + (\rho_b gh\cos\alpha - p)\tan\phi}{\rho_b gh \sin\alpha}$$

$p = \rho_w gmh \cos\alpha$

$$F_s = \frac{c' + (\rho_b - m\rho_w)gh\cos\alpha\tan\phi}{\rho_b gh\sin\alpha}$$

$F_s \le 1$ failure

Cohesionless soil

$c' = 0$ if cohesionless

$$F_s = \frac{(\rho_b - m\rho_w)\tan\phi}{\rho_b \tan\alpha}$$

F_s =1 at maximum stable slope

$$\tan\alpha_{\max} = \frac{(\rho_b - m\rho_w)\tan\phi}{\rho_b}$$

If dry, cohesionless, $\tan\alpha_{\max} = \tan\phi$, $\alpha_{\max} = \phi$

Iverson and Major (1986), WRR

Normal force (stress): $(\rho_b - \rho_w)gh\cos\alpha + \text{seepage force}(z)$

Driving stress: $(\rho_b - \rho_w)gh\sin\alpha + \text{seepage force}(x)$

where $\rho_b - \rho_w$ is buoyant weight of wet soil.

If parallel seepage, seepage force in (z) = 0

$f_{seepage} = \frac{q}{K}\rho_w g$ where q is water flux per unit volume.

Darcy's law: $q = K\sin\alpha$ where K is hydraulic conductivity.

$f_{seepage} = \rho_w g \sin\alpha$

seepage force in (x) = $\rho_w g h \sin\alpha$

$$F_s = \frac{(\rho_b - \rho_w) g h \cos\alpha \tan\phi}{\rho_b g h \sin\alpha}$$