



# **TALUDES ROCHOSOS CONDICIONAMENTOS GEOLOGICOS**

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The image features a landscape with a bright yellow horizon line, suggesting a sunrise or sunset. The sky above is a dark grey color. The text is centered in the lower half of the image.

# **CARACTERISTICAS DOS MACICOS ROCHOSOS**

# COMPARAÇÃO ENTRE MACIÇOS DE SOLO E DE ROCHA

- ⇒ MATERIAL IDEAL: contínuo, isotrópico, homogêneo, idealmente elástico.
- ⇒ SOLO: contínuo (poroso), +/- homogêneo, às vezes isotrópico, afasta-se de elástico.
- ⇒ ROCHA: descontínuo, às vezes heterogêneo e isotrópico e não elástico em maciço fraturado.  
**FRATURAS SÃO PLANOS DE FRAQUEZA DO MACIÇO.**



MEIO GRANULAR



MEIO DESCONTINUO

# MACICO DESCONTINUO

Bloco de rocha  
intacta



Fraturas  
(descontinuidades)

**NÃO É UM MACICO CONTINUO,  
MAS CONTEM DESCONTINUIDADES**



# DESCONTINUIDADES SÃO PLANOS DE FRAQUESA, CONDICIONANTES DA ESTABILIDADE CONFORME SUA POSICAO

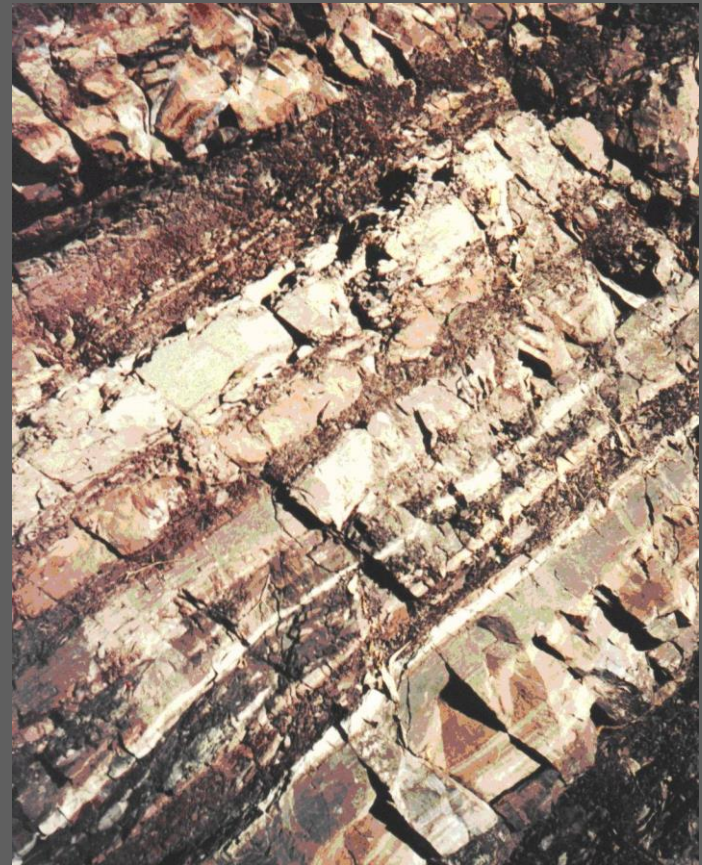


# PODEM CONTER

**HETEROGENEIDADE**

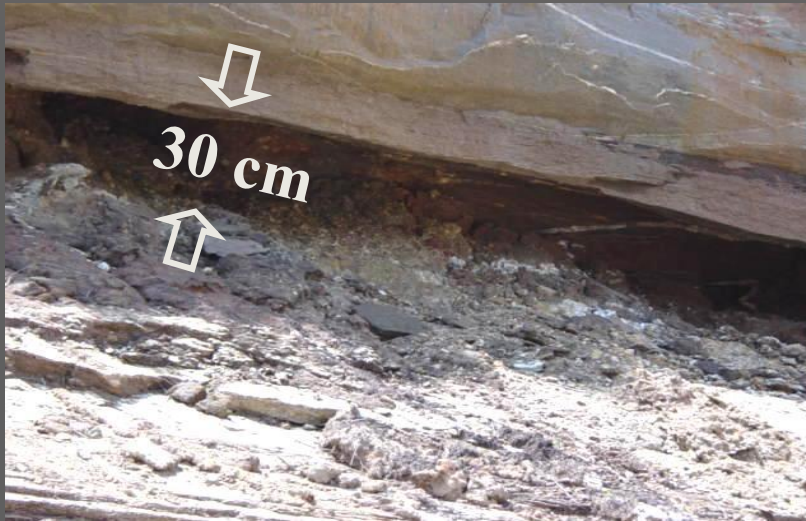
OU

**ANISOTROPIA**





# PODEM CONTER PLANOS DE FRAQUEZA PREENCHIDOS



**D. Derre:**

**Coesão:**

**Angulos de atrito:**

**Zero para fraturas contínuas.**

**8° a 15° para preenchimento argiloso**

**16° a 23° para preenchimentos intermediários**

**24° a 32° para preenchimentos arenosos**

# CAMADAS DE SILTITO ALTERADO EM ARENITO SILICIFICADO



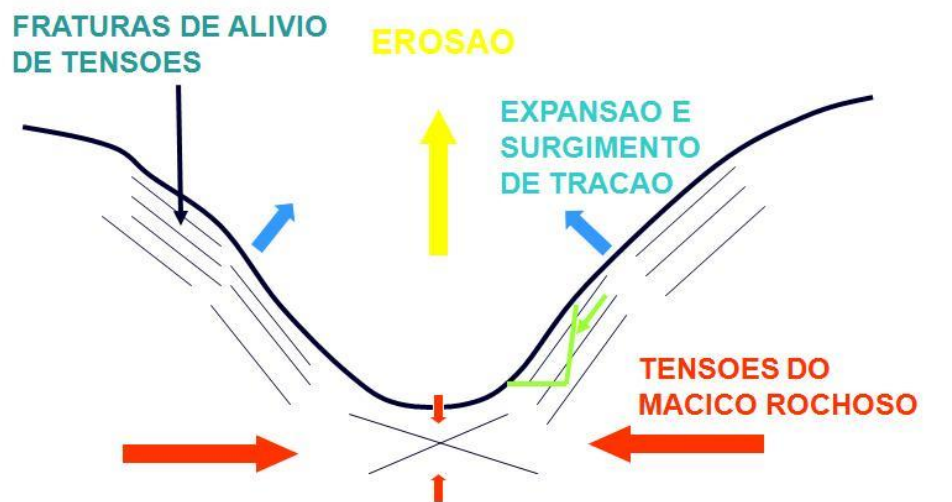
## CAMADAS DE BIOTITA XISTO NO GNAISSE



**POSSIBILIDADE DE INCLUSOES MAIS  
FRACAS EM ROCHA DE BOA QUALIDADE**  
**XISTO ALTERADO EM QUARTIZITO SÃO**



# FRATURAS PARALELAS A SUPERFICIE TOPOGRAFICA (juntas de alivio de carga)

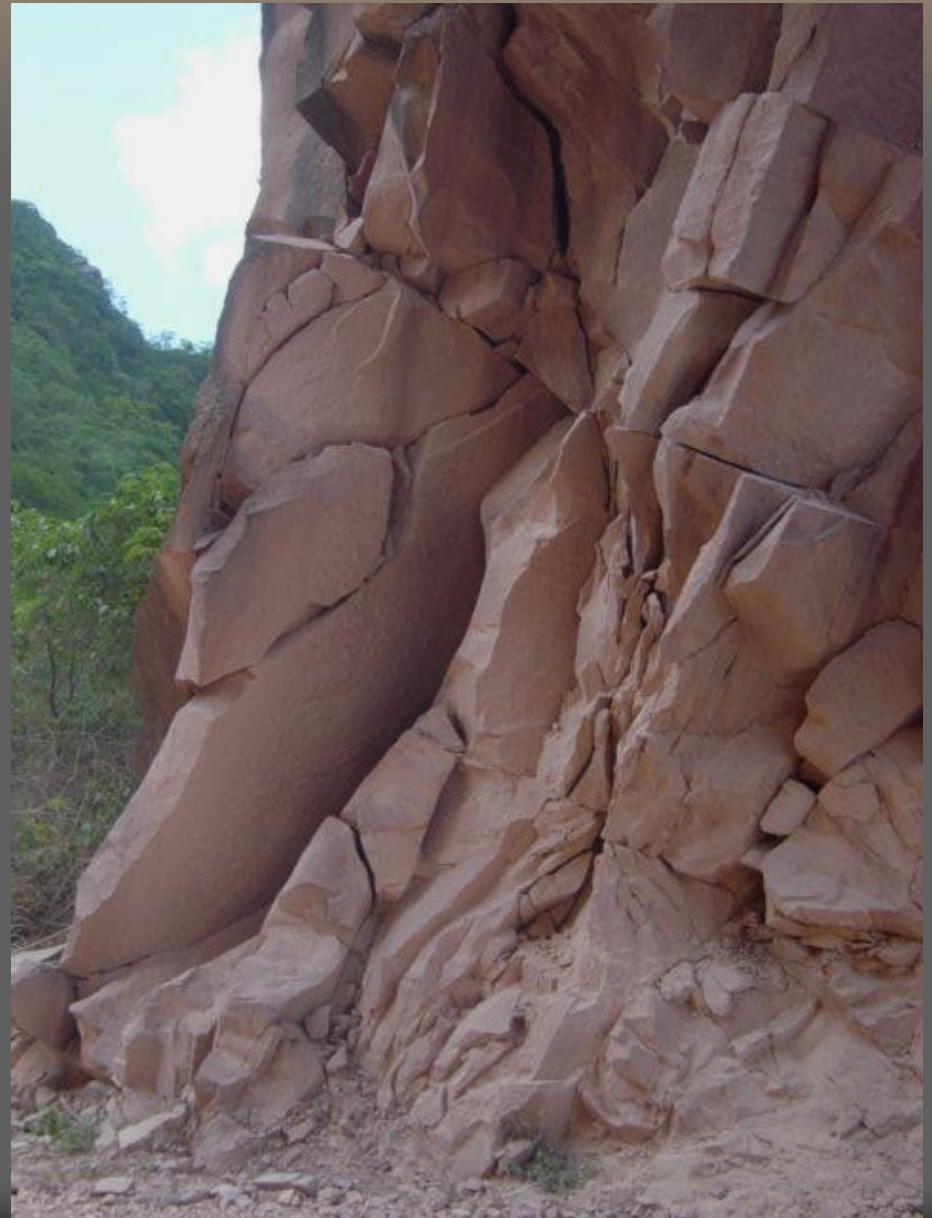
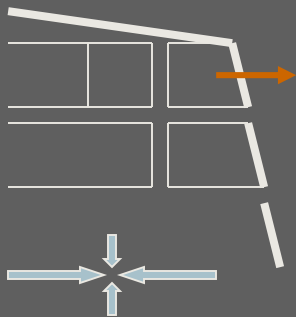


# DIACLASES DE ALIVIO DE CARGA



# ALIVIO DE TENSOES

Abertura das fraturas  
proximo as superficies de  
escavacao



# ALIVIO DE TENSÕES HORIZONTAIS





# FALHAS

## FALHA DO GNAISSE (BACIA DE S. PAULO)



## ESPELHO DE FALHA E ESTRIAS DE ATRITO

# PLANOS DE XISTOSIDADE OU FOLIAÇÃO

FILITO



GNAISSE



# FRATURAMENTO





# DOBRAS

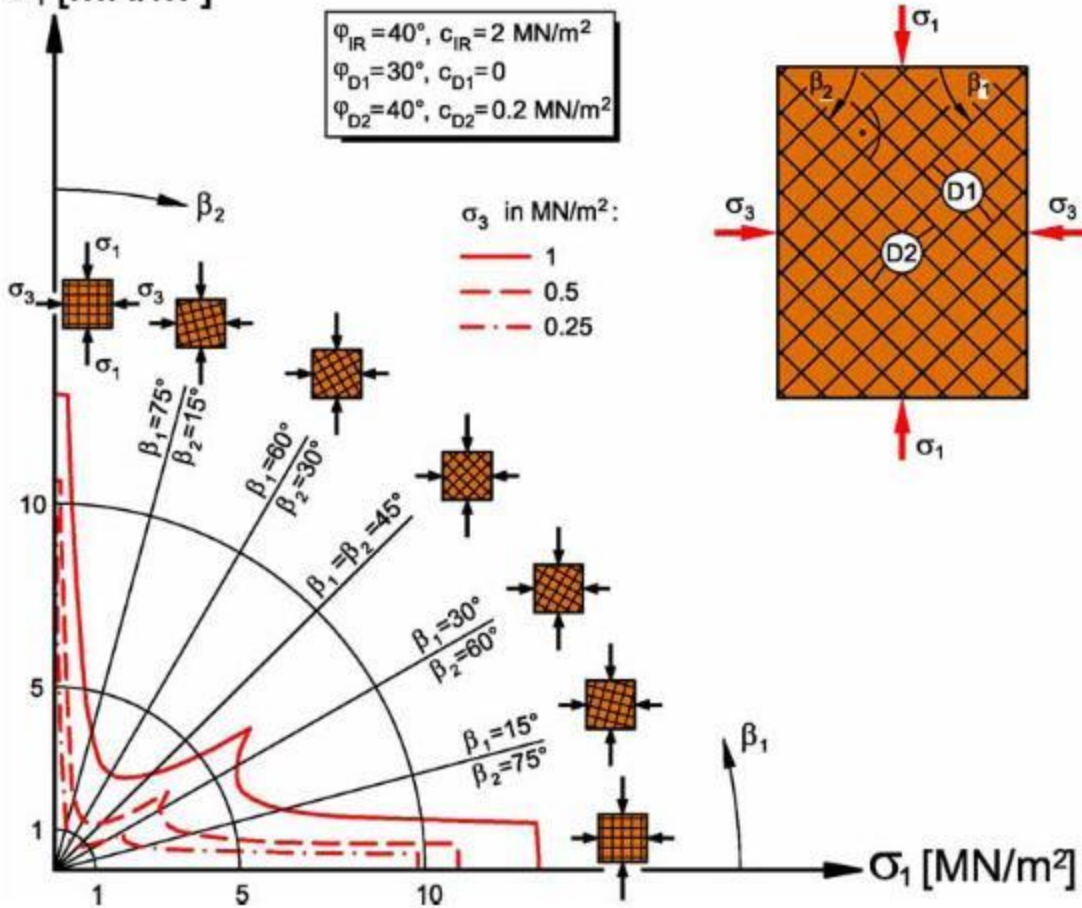


$\sigma_1$  [MN/m<sup>2</sup>]

$\varphi_{IR} = 40^\circ, c_{IR} = 2 \text{ MN/m}^2$   
 $\varphi_{D1} = 30^\circ, c_{D1} = 0$   
 $\varphi_{D2} = 40^\circ, c_{D2} = 0.2 \text{ MN/m}^2$

$\sigma_3$  in MN/m<sup>2</sup>:

— 1  
- - - 0.5  
- · - 0.25



# Solos Residuais

*Solo Residual  
Maduro*

*Solo Saprolítico  
ou Residual Jovem*

*Rocha Alterada*

solo

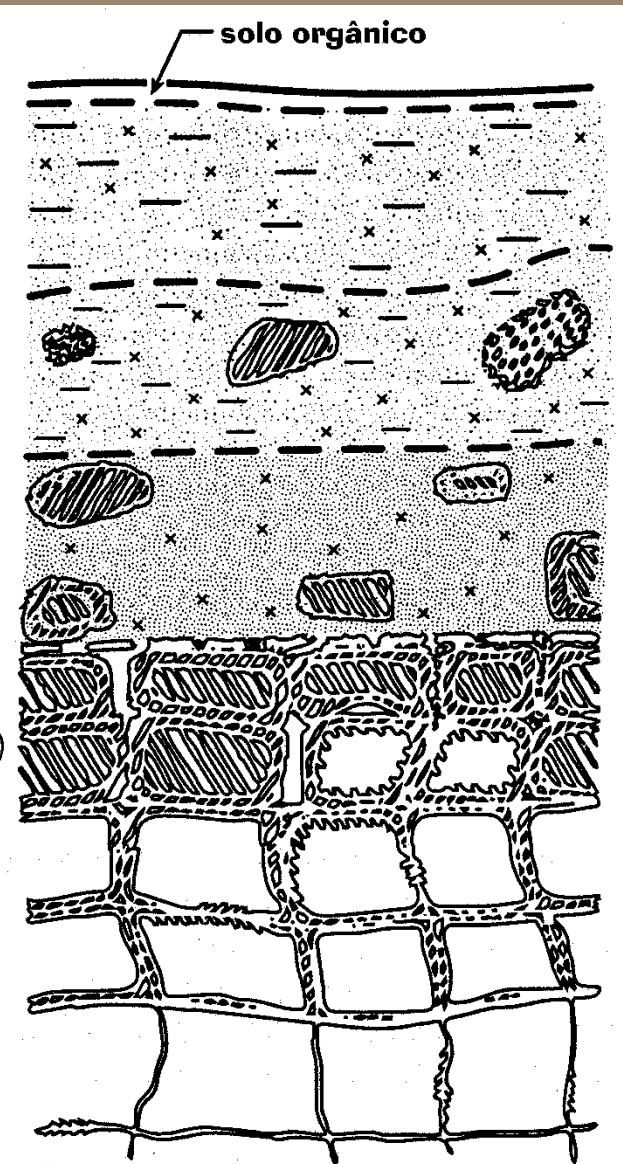
completamente  
intemperizado

altamente  
intemperizado

moderadamente  
intemperizado  
(50% a 90% rocha)

levemente  
intemperizado

rocha



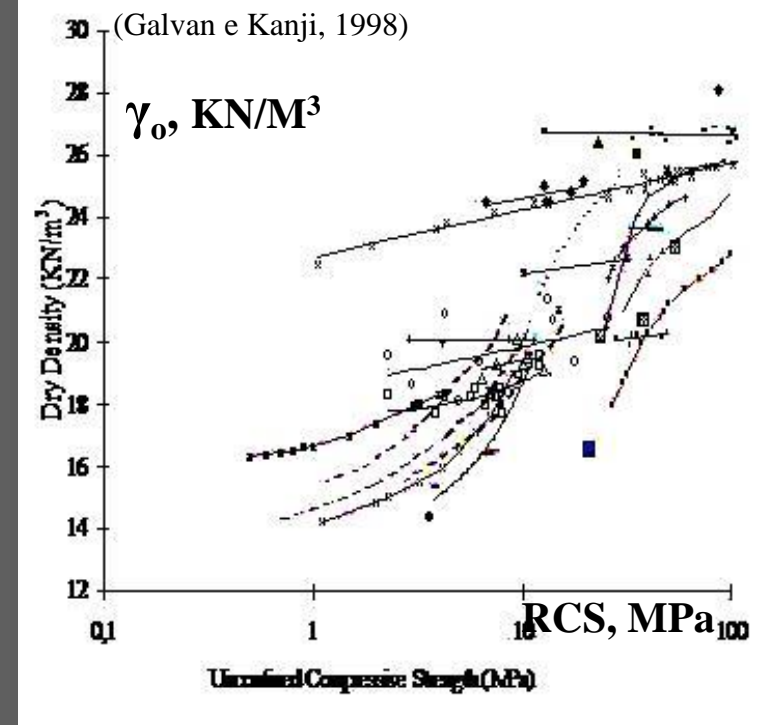
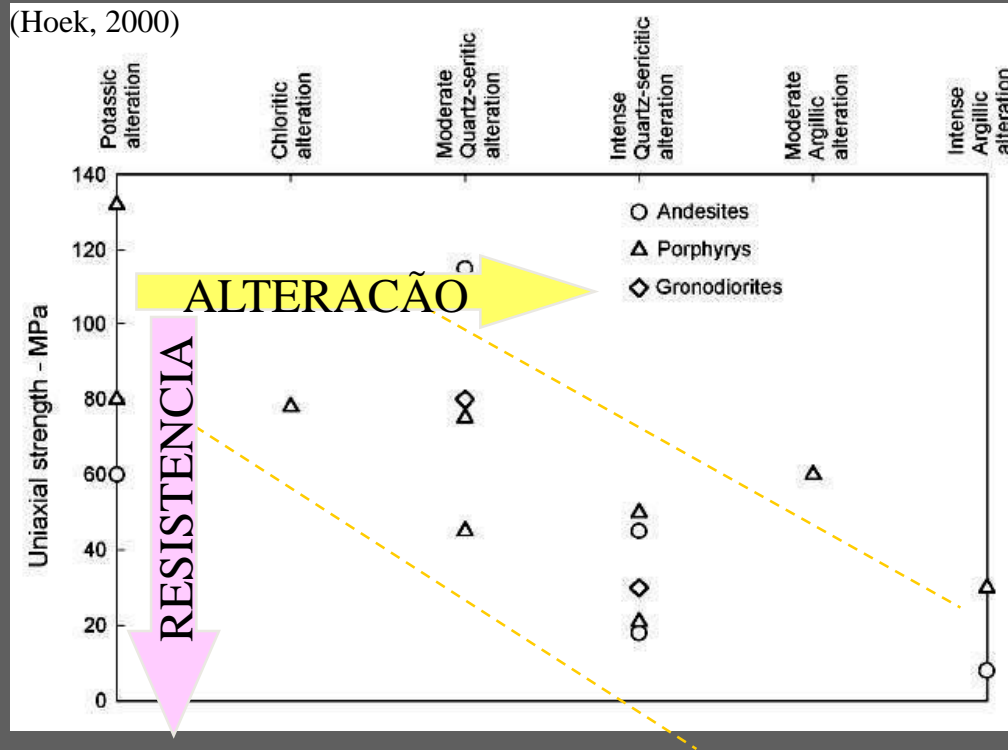
OBS: Existem outras classificações

# INTEMPERISMO DIFERENCIAL



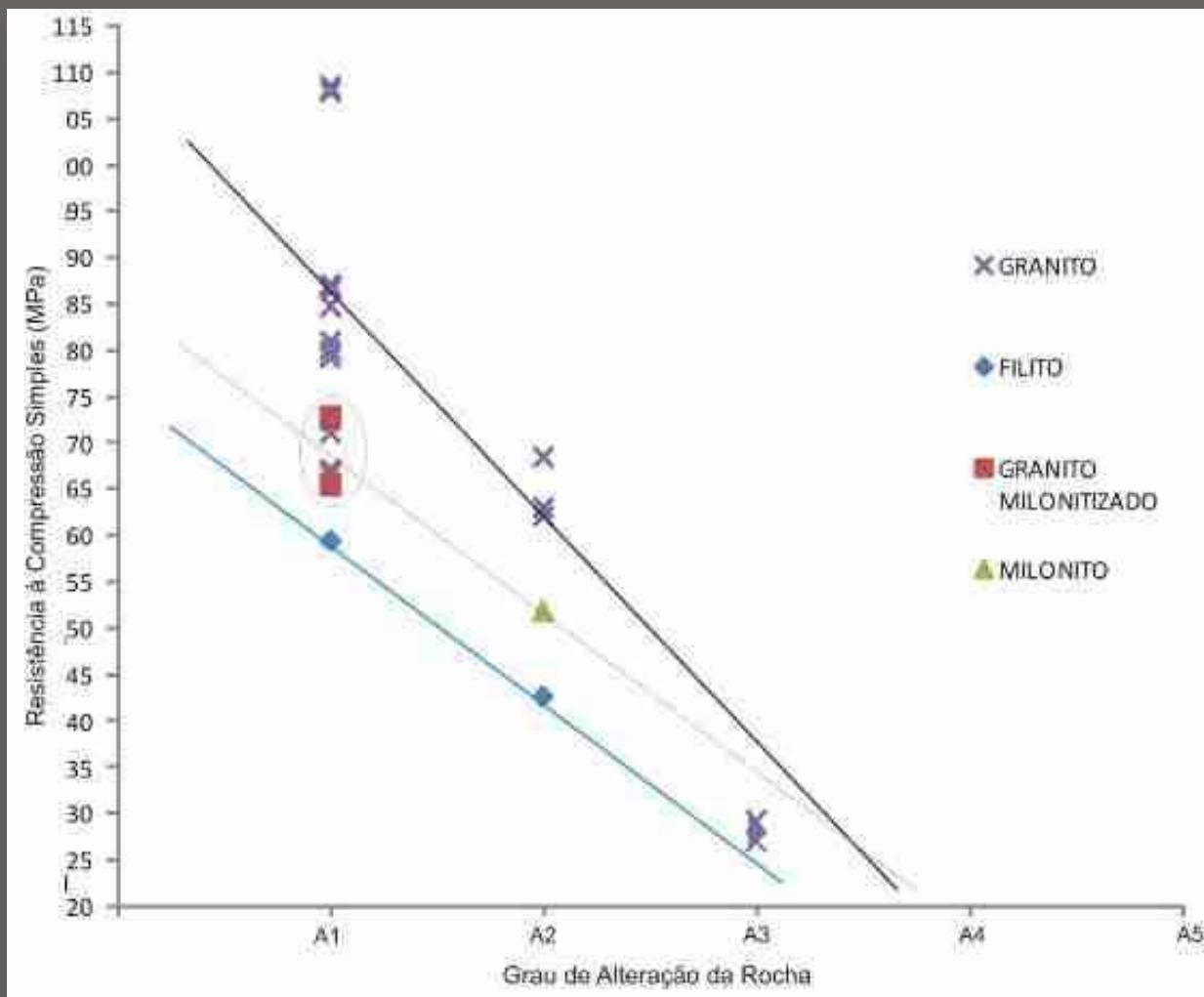
# RESISTENCIA DA ROCHA DIMINUIE COM A ALTERAÇÃO DOS MINERAIS

(Hoek, 2000)

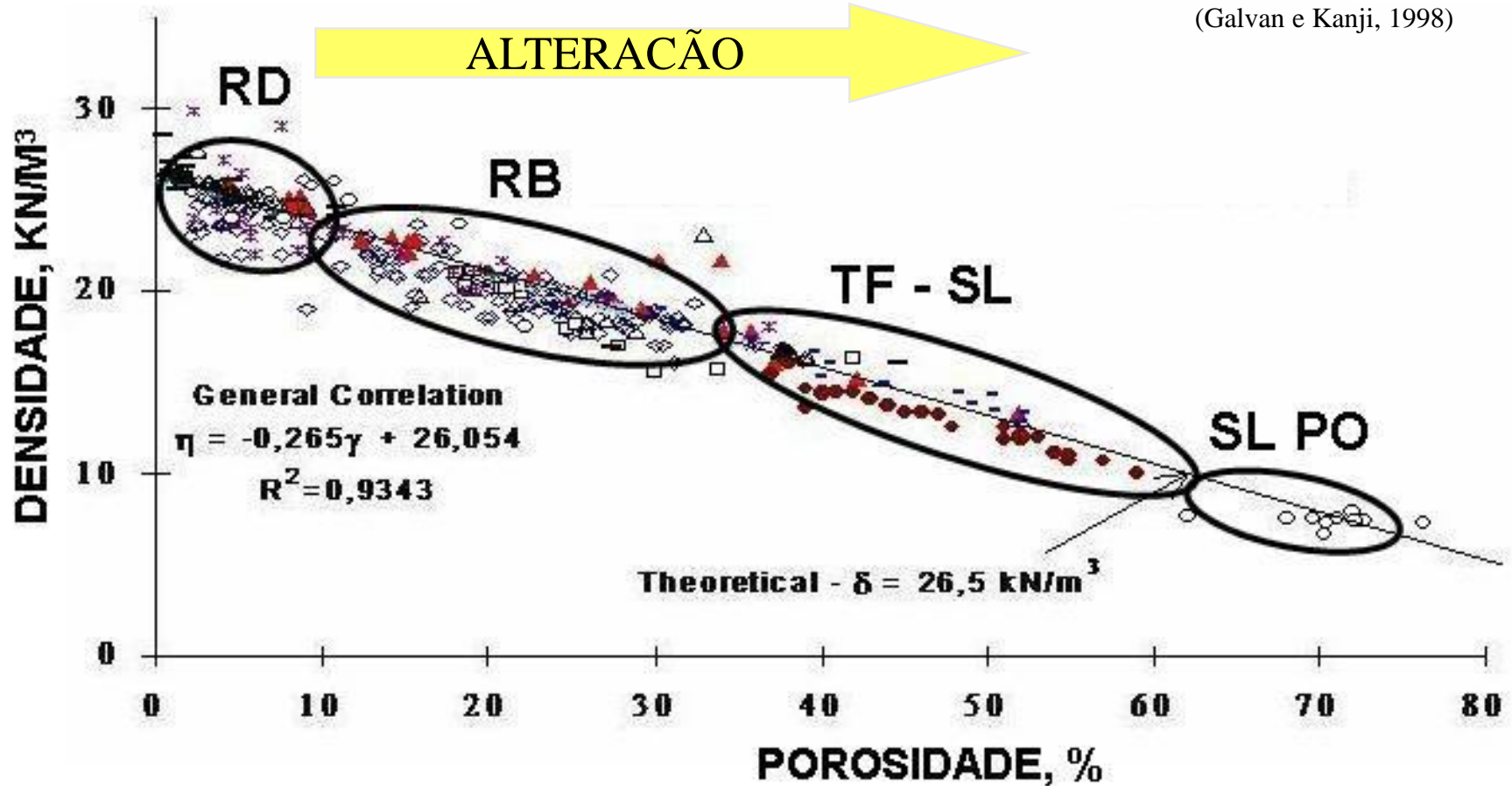




# DIMINUIÇÃO DA RESISTÊNCIA COM A ALTERAÇÃO



(Galvan e Kanji, 1998)



RD – Rocha Dura  
RB- Rocha Branda

TF / SL – Tufos Vulcanicos e Solo  
SL PO – Solos Altamente Porosos



PLANOS DE  
ESTRATIFICAÇÃO  
NÃO PARALELOS  
AO TALUDE

# NA AUSENCIA DE DEFEITOS DA ROCHA:





A landscape image with a bright yellow horizon line, possibly representing a sunset or sunrise. The sky above is a mix of light blue and white, with some darker clouds. The foreground is a dark grey gradient.

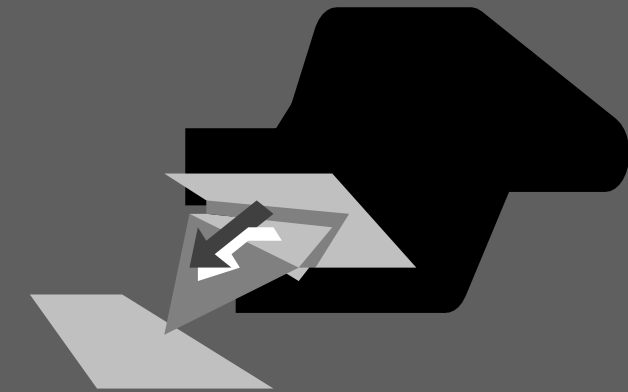
# **MODOS DE RUPTURA**

# MODOS DE RUPTURA

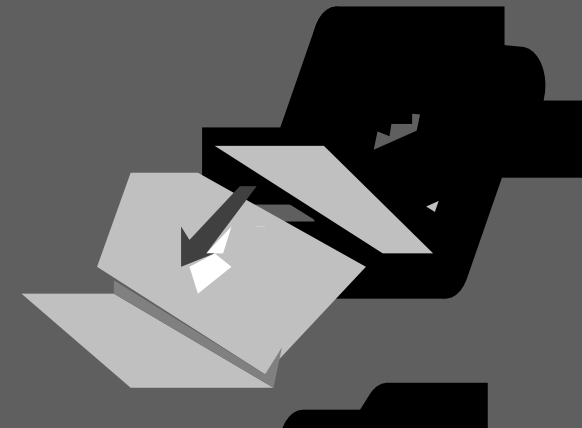
SUPERFICIE CIRCULAR



DESLIZAMIENTO DE CUNA



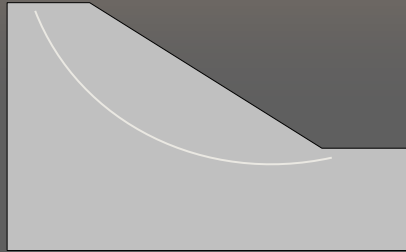
SUPERFICIE PLANA



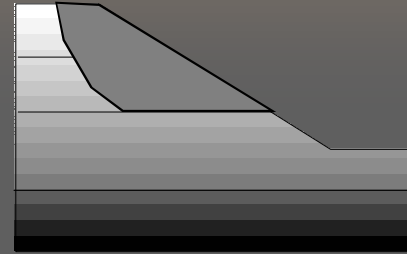
VOLTEO (“TOPPLING”)

# MODOS COMUNES DE RUPTURA DE TALUD EM ROCA

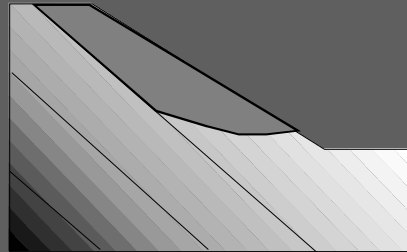
Homogeneous



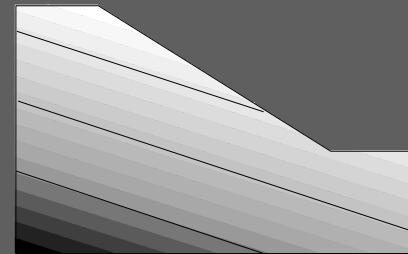
Horizontally layered



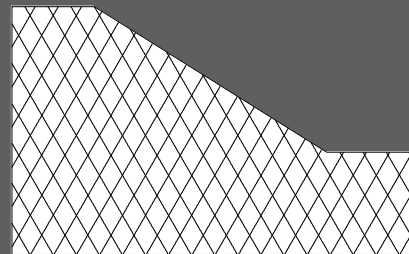
Inclined layered,  
dip greater than the slope  
(not daylighting)



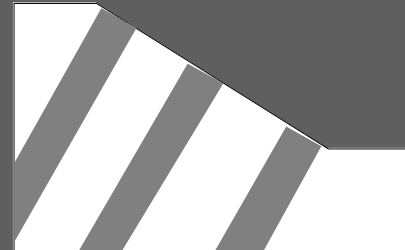
Inclined layered,  
dip smaller than the slope  
(daylighting feature)



Complex cases



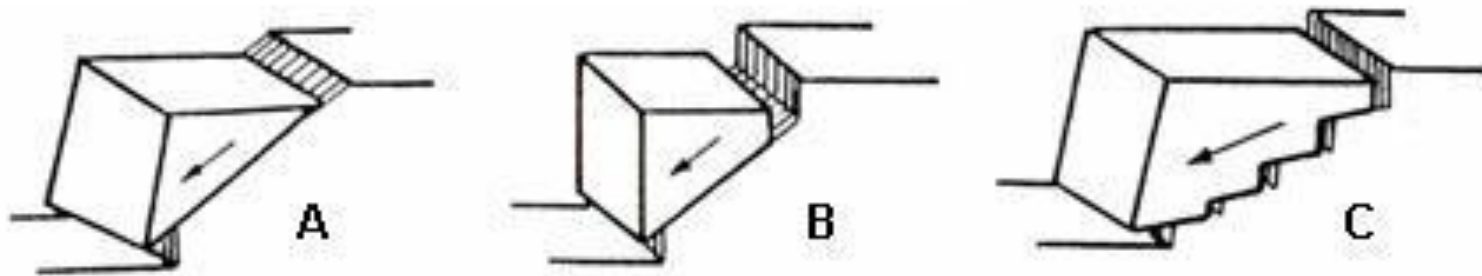
Complex case with  
intrusive rock dikes



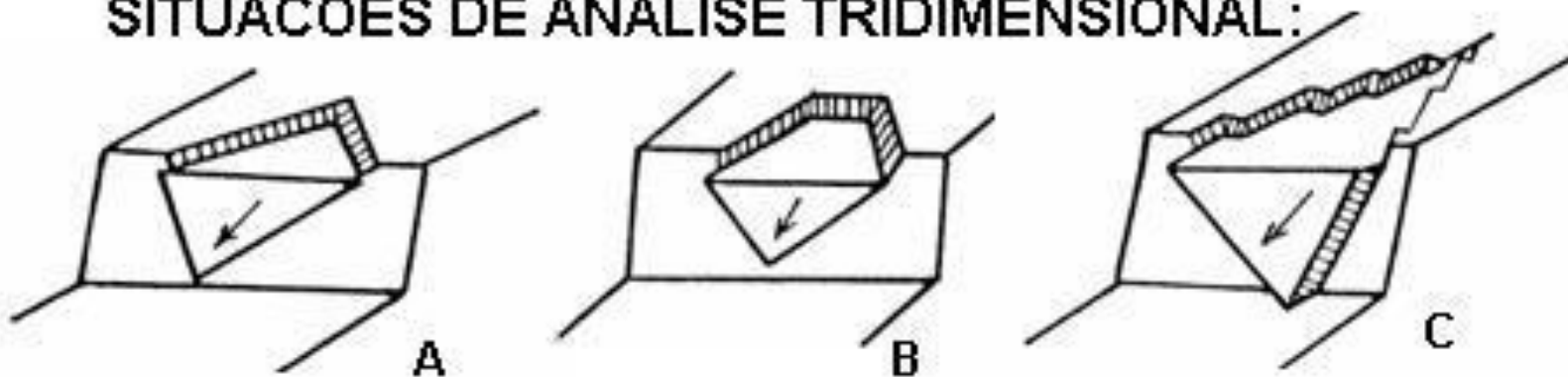


# RUPTURA POR DESCONTINUIDADE CONDICIONANTE

SITUACÕES DE ANÁLISE BIDIMENSIONAL:



SITUACÕES DE ANÁLISE TRIDIMENSIONAL:



# EXEMPLOS

FILITO

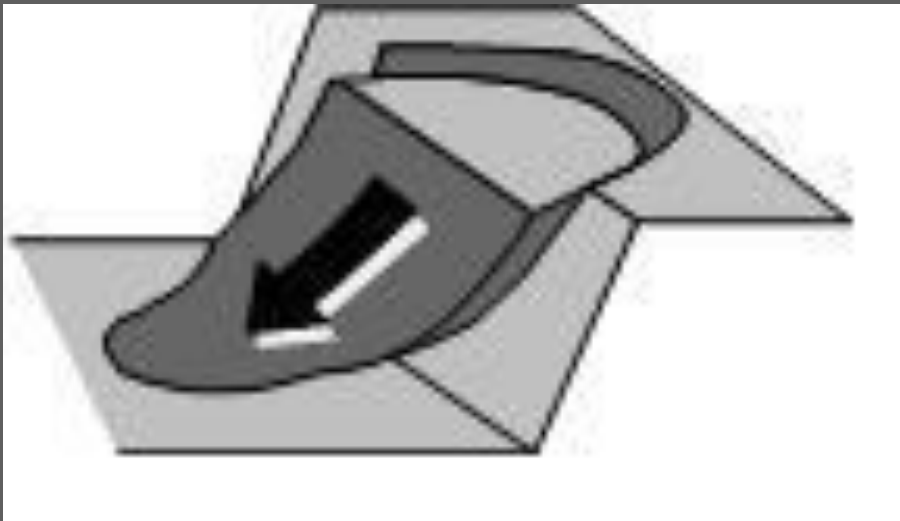


VAIONT

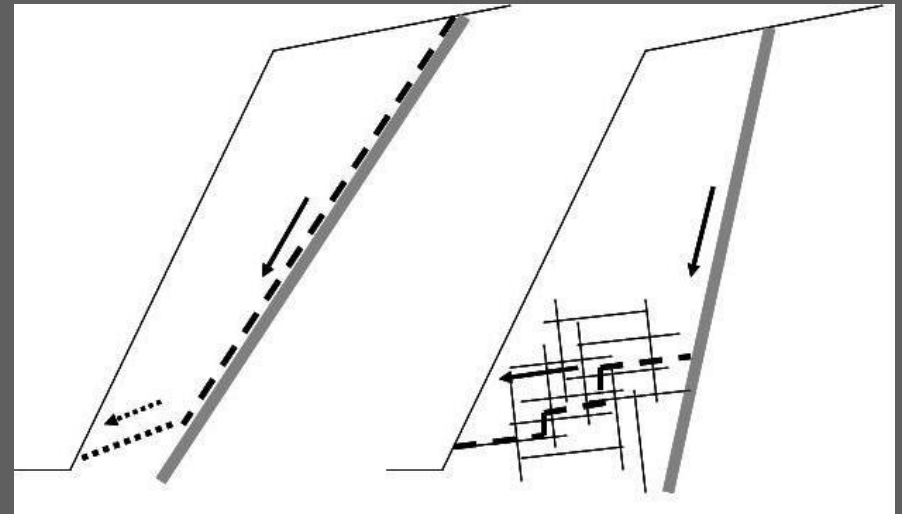


# RUPTURA POR ROCHA INTACTA

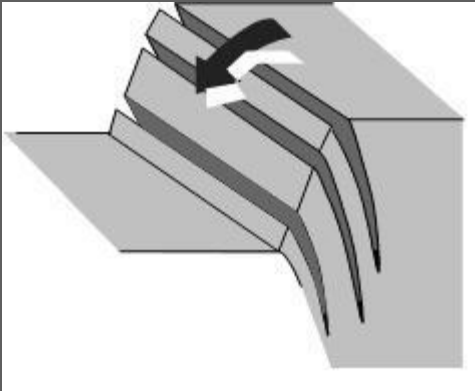
ROCHA INTACTA DE BAIXA  
RESISTENCIA



# CASOS COMPOSTOS



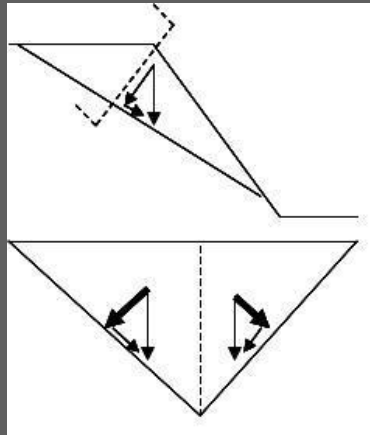
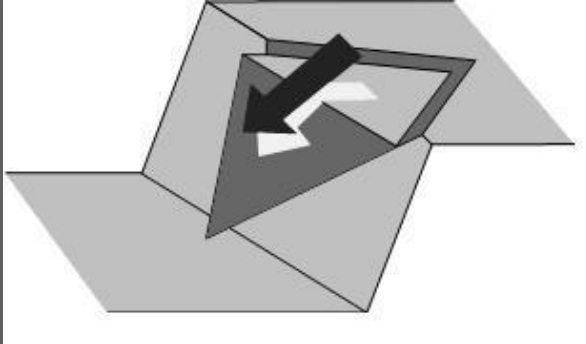
# RUPTURA POR TOMBAMENTO (TOPPLING)



# **RUPTURA POR DESMORONAMENTO DE BLOCOS**



# EQUILÍBRIO LIMITE PLANOS CONJUGADOS

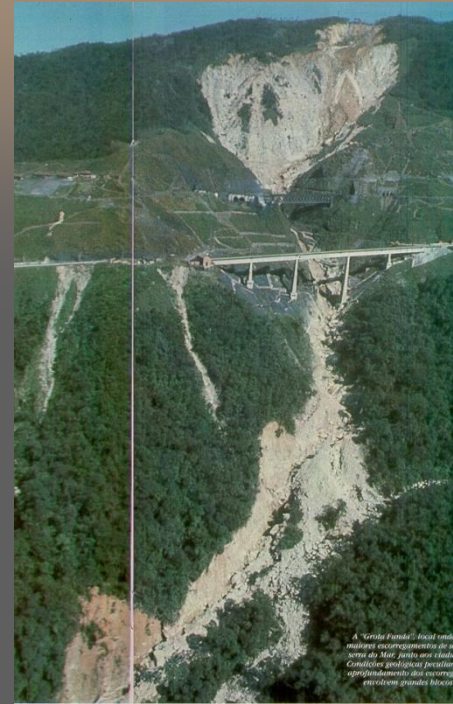


ANÁLISES POR PAULING, JAEGGER, KOVARI, ETC. EXEMPLO  
DE PROGRAMAS COMPUTACIONAIS:  
SWEDGE – WEDGE – EZSLIDE - STABLOCK

# CORRIDAS DE DETRITOS (DEBRIS FLOWS)



# DEBRIS FLOWS CONSECUENCIAS



PATH OF 1997 OUTFLOW FROM MORANE-DAMMED QUIN MERE LAKE, MOUNTAIN CREST MOUNTAINS



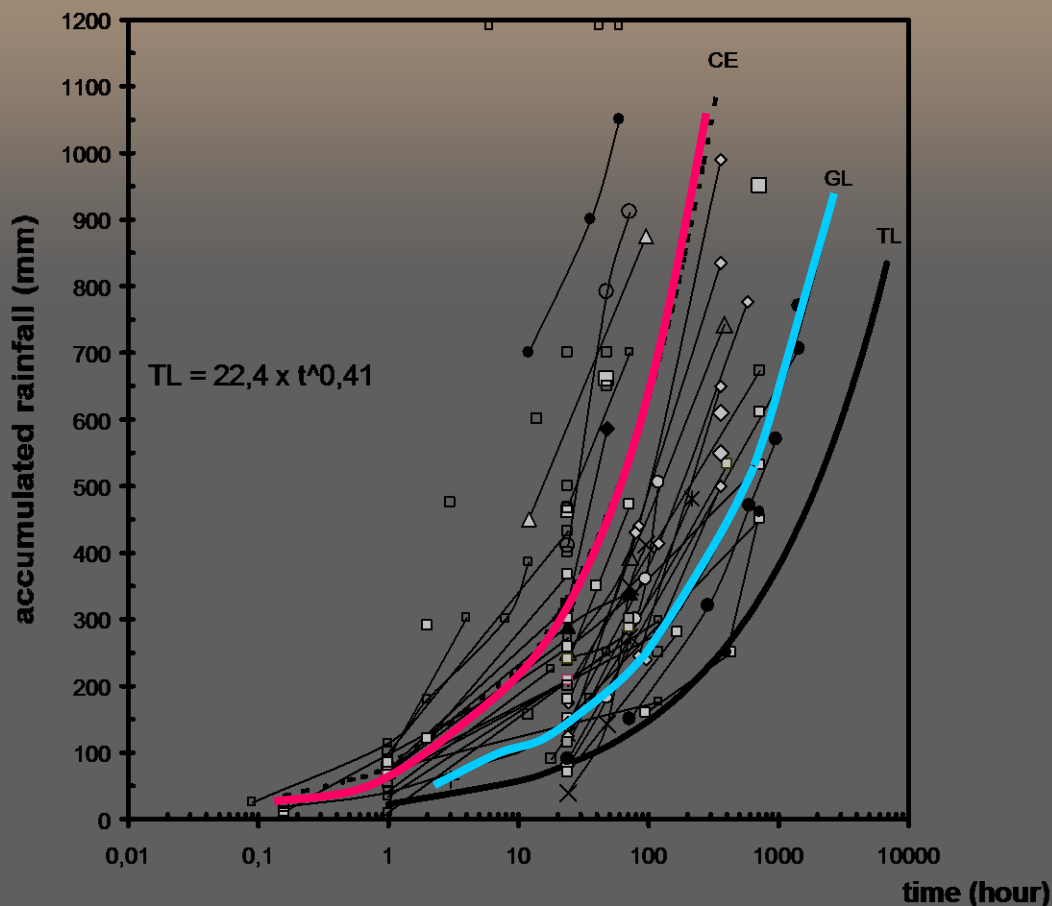


Curva TL – triggering line, a partir da qual as chuvas já podem deflagrar escorregamentos;

Curva GL – generalized landslides, a partir da qual os escorregamentos certamente ocorrem e são generalizados

Curva CE – catastrophic events, a partir da qual os escorregamentos tem efeitos catastroficos e em geral acompanhados de corridas de detritos

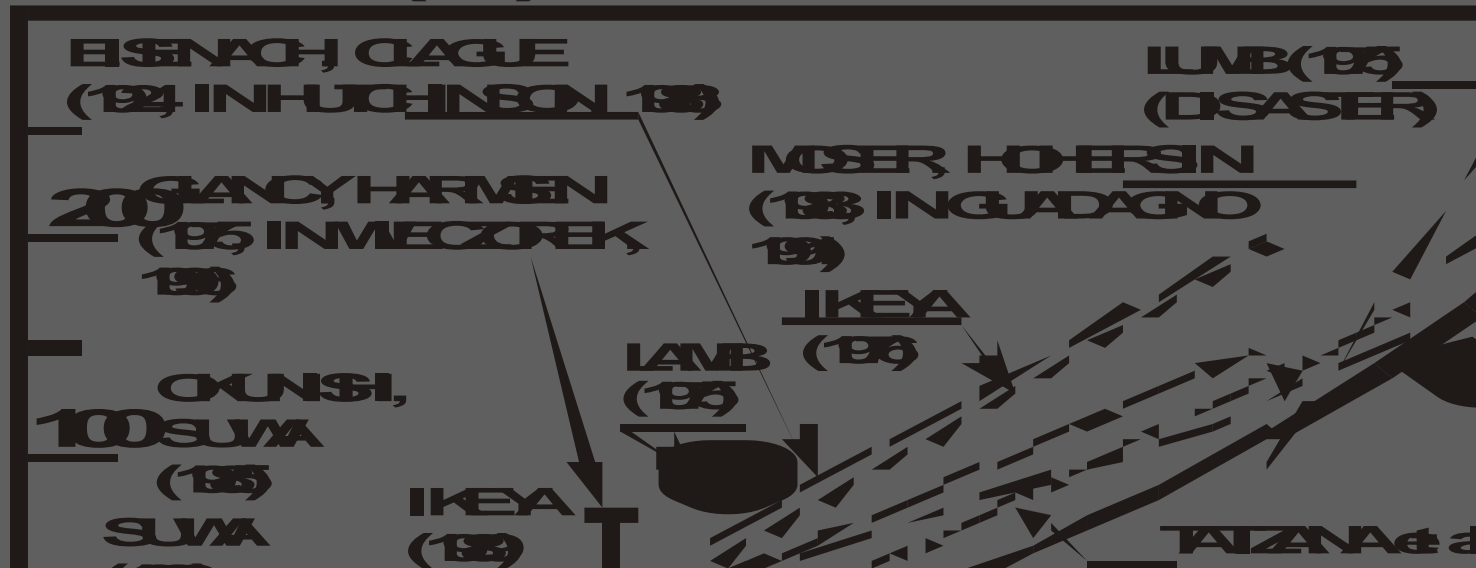
Apud Kanji et al (2003)




- Colombia (some cases)
  - + Antofagasta91(CHILE)
  - ▲ SARaras67(BR)
  - ◆ R.Janeiro88(BR)<sup>1</sup>
  - △ Ubatuba96(BR)
  - × MtQuieto00(BR)
  - Outros (National Cases)
  - Critical Curve-Triggering Limit (TL)
  - Limit Curve of Catastrophic Events (CE)
  - Maiquetia99(VEN)
  - ◆ Caragua67(BR)
  - △ Tubarao74(BR)
  - Cubatao94(BR)
  - \* Via Anchieta99(BR)
  - C.Jordao00(BR)
  - Outros (Internacional Cases)
  - Limit Curve of Generalized Landslides (GL)
- 1 = multiples stations

# COMPARISON OF PROPOSED CURVE WITH OTHER EXISTING CRITERIA FOR LANDSLIDES INITIATION

**RAINFAL,  $R$  (mm)**



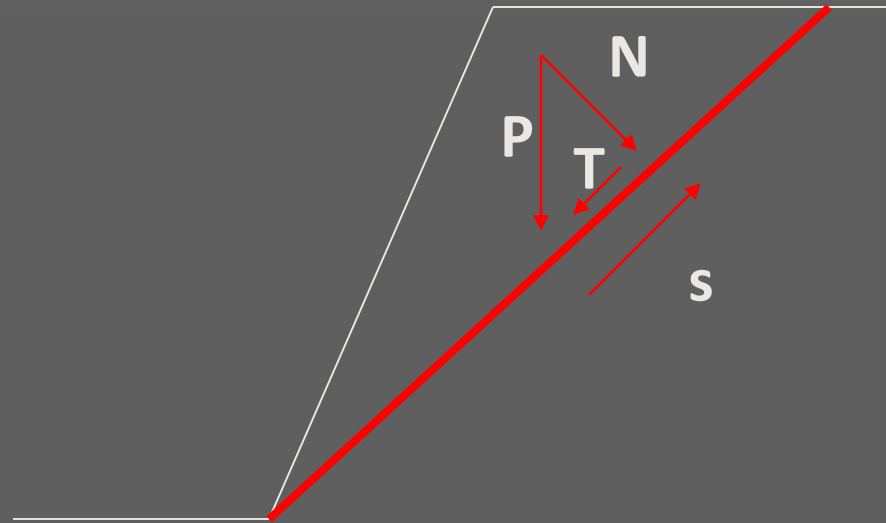


**A ANALISE DESTAS SITUAÇÕES  
REQUER CONHECIMENTO DA  
RESISTÊNCIA AO DESLIZAMENTO DE FRATURAS  
(DESCONTINUIDADES ROCHOSAS)**

$$s = N \cdot \tan \Phi$$

$$N = P \cdot \cos \alpha$$

$$T = P \cdot \sin \alpha$$



$$FS = s / T = (P \cdot \cos \alpha \cdot \tan \Phi) / P \cdot \sin \alpha$$

$$\text{Para } FS = 1: P \cdot \sin \alpha / P \cdot \cos \alpha = N \cdot \tan \Phi$$

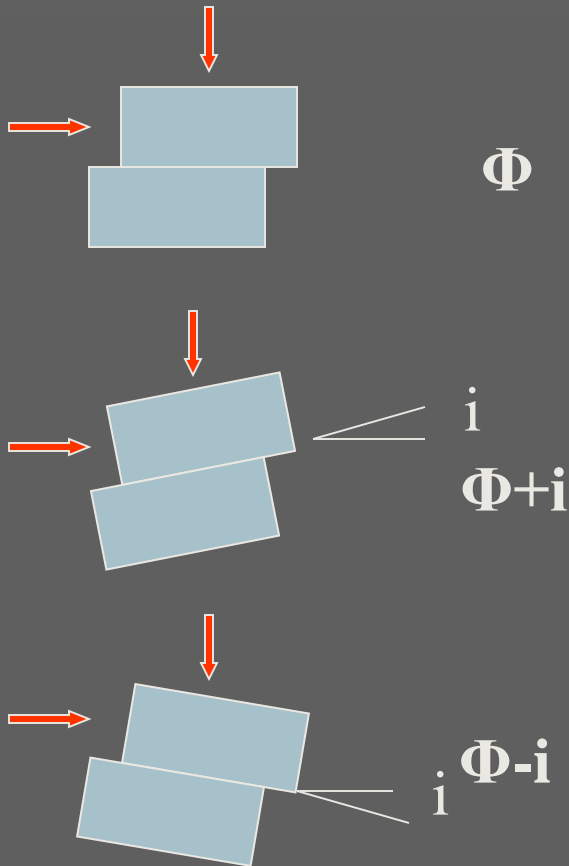
$$\tan \Phi = \tan \alpha$$

$$FS = \tan \Phi / \tan \alpha$$

# ANGULO DE ATRITO

## DE FRATURAS ROCHOSAS

$$T = (c.A) \tan(\phi + i)$$



### TIPOS DE FRATURAS: $\Phi$ approx.

Plana, lisa e polida:  $26^\circ - 33^\circ$  ( $30^\circ$ )

Plana e pouco rugosa:  $35^\circ$

Lisa e pouco ondulada:  $35^\circ$

Lisa e muito ondulada:  $40^\circ$

Ondulada e muito rugosa:  $40^\circ - 45^\circ$

**Em rocha micacea:  $15^\circ - 25^\circ$  !!!**

**Preenchimento arenoso = areia**

**Preenchimento argiloso 0,5 – 0,66 argila**

$$\Phi_{res} = 46,6 / IP^{0,446} \quad (\text{Kanji, 1974})$$

# ESTIMATIVA DO ANGULO DE ATRITO DE FRATURAS PELO CRITERIO DE BARTON

$$\tau = \sigma_n \cdot \tan [ JRC \cdot \log ( JCS / \sigma_n ) + \phi_r ]$$

$$\Phi_r = (\phi_b - 20^\circ) + 20 (r/R)$$

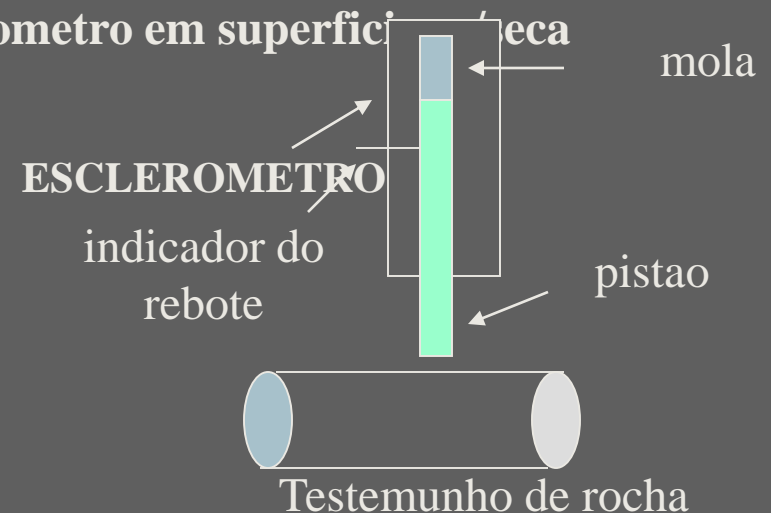
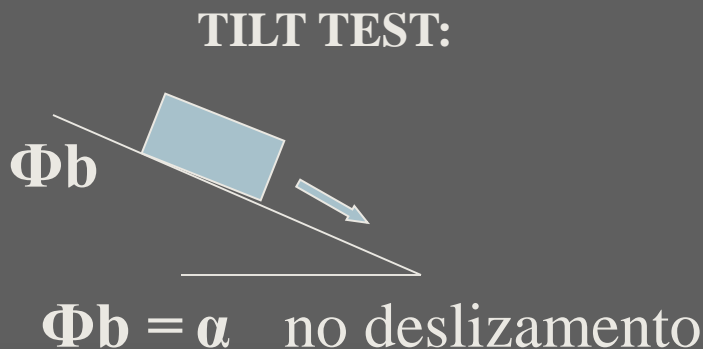
JRC (Joint Roughness Coefficient): 0-2 (lisas) a 18-20 (muito rugosas)

JCS (Joint Coefficient of Strength):  $\sigma_c$  da rocha ou do esclerometro

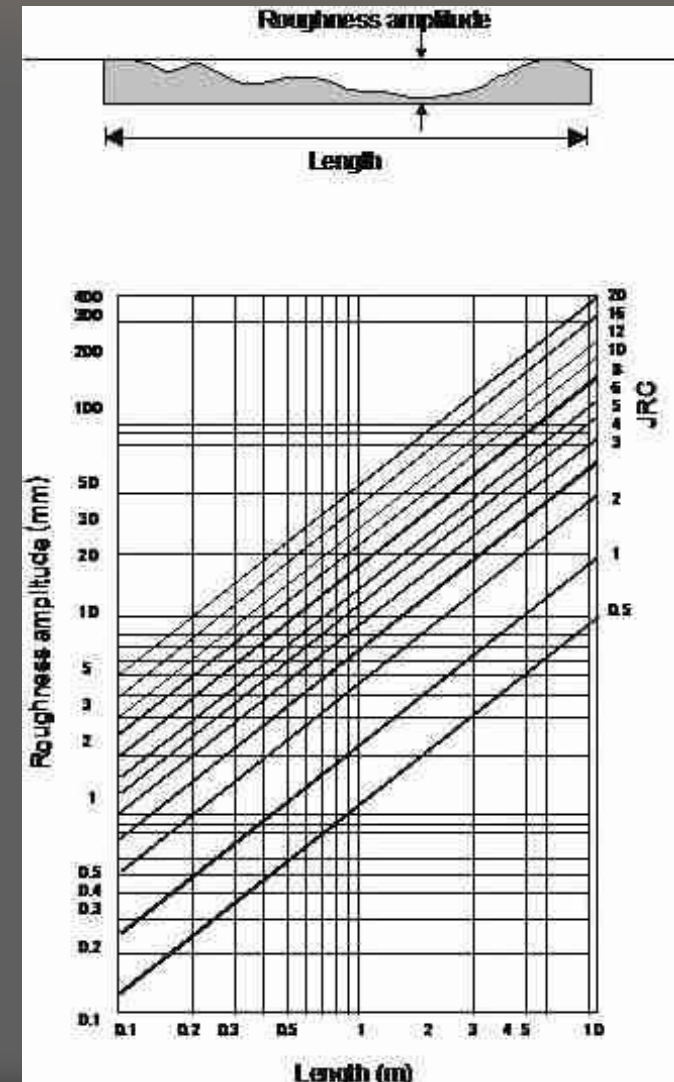
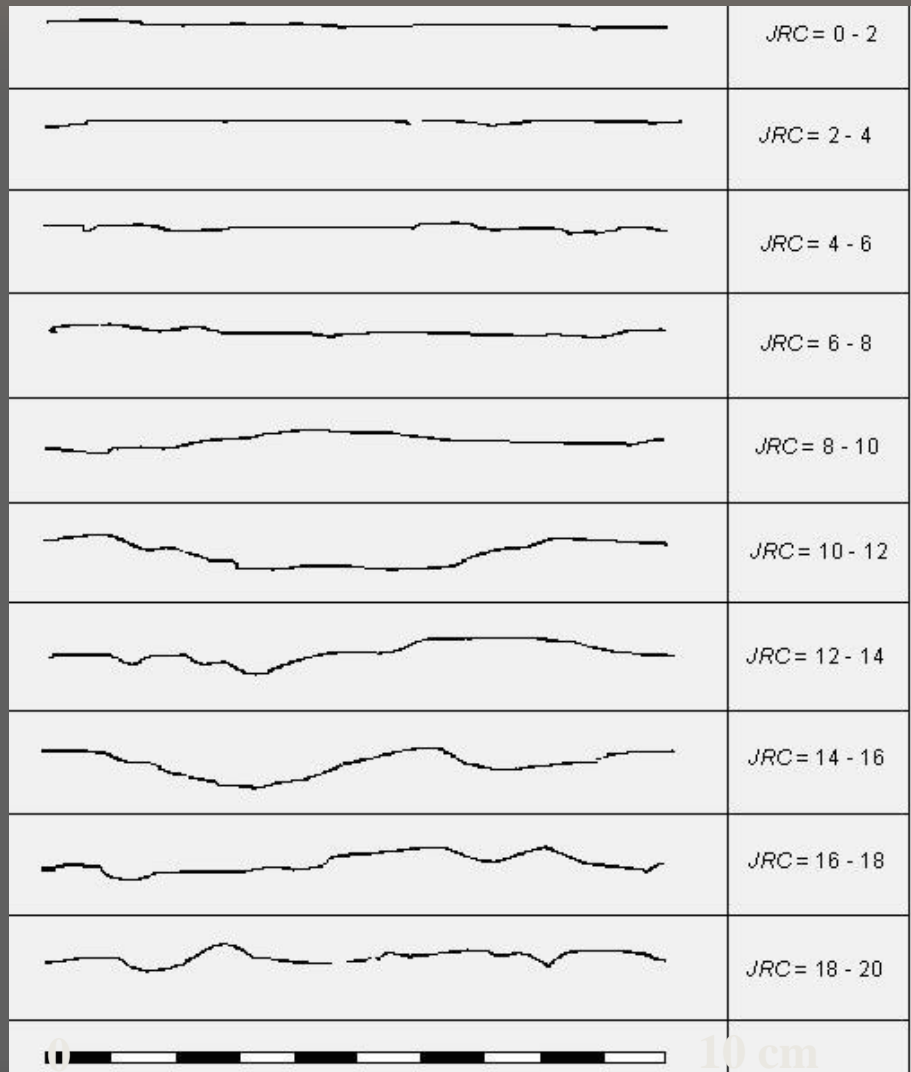
$\Phi_b$  obtido do “tilt test”

r – repique do esclerometro em superficie alterada/molhada

R - repique do esclerometro em superficie lisa



# JRC – Joint Roughness Coefficient (Barton)



# DETERMINAÇÃO DA RESISTÊNCIA AO CISALHAMENTO



PORTÁTIL -  
CAMPO



TILT TEST

LABORATÓRIO



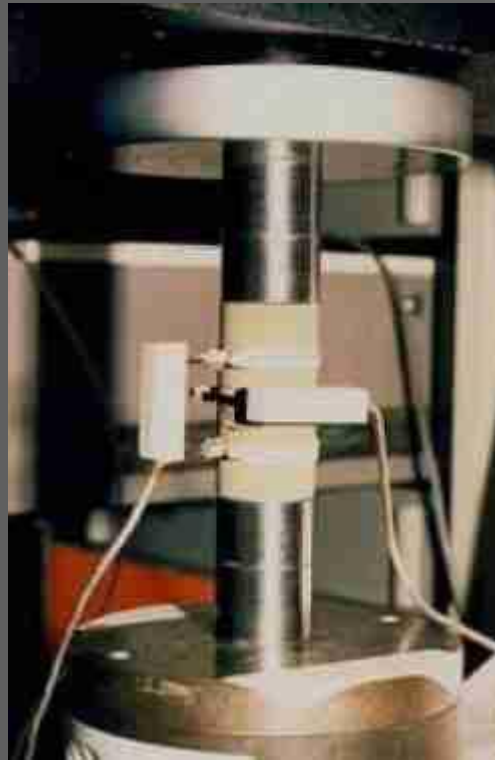


# PROPRIEDADES DA ROCHA INTACTA

ESCLERÔMETRO SCHMIDT



COMPRESSÃO SIMPLES



COMPRESSÃO TRIAXIAL



ENSAIO BRASILEIRO - TRAÇÃO



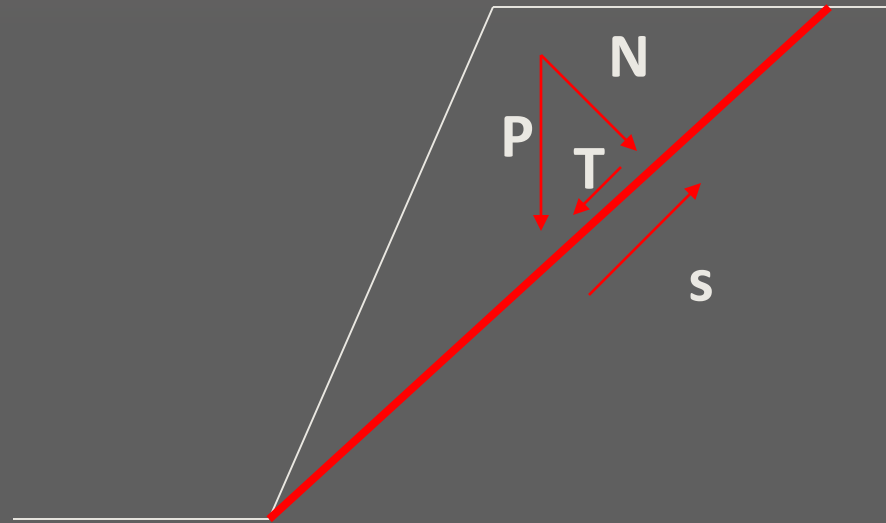


# **AVALIAÇÃO DA ESTABILIDADE DO TALUDE**

$$s = N \cdot \tan \Phi$$

$$N = P \cdot \cos \alpha$$

$$T = P \cdot \sin \alpha$$



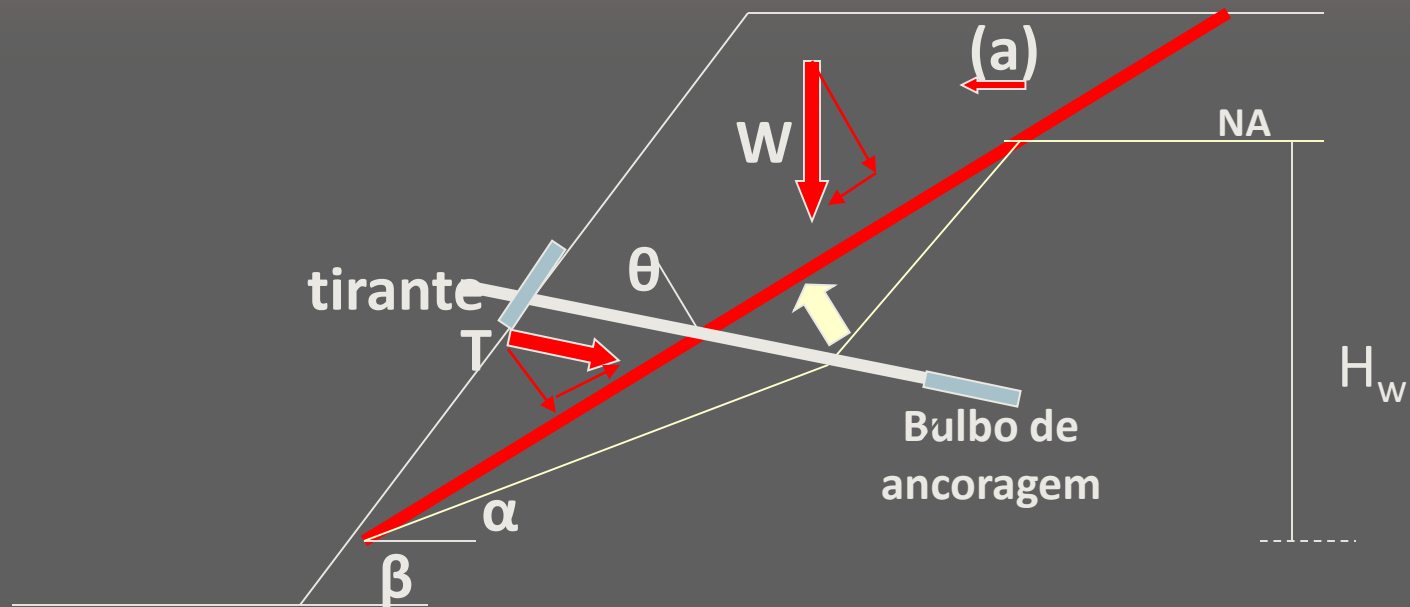
$$FS = s / T = (P \cdot \cos \alpha \cdot \tan \Phi) / P \cdot \sin \alpha$$

$$\text{Para } FS = 1: P \cdot \sin \alpha / P \cdot \cos \alpha = N \cdot \tan \Phi$$

$$\tan \Phi = \tan \alpha$$

$$FS = \tan \Phi / \tan \alpha$$

# ANALISE DE ESTABILIDADE DE TALUDE ATIRANTADO

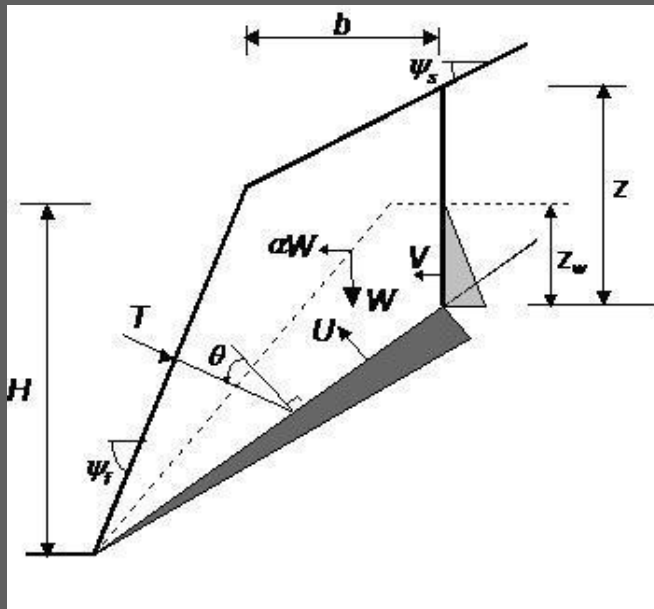


$$FS = (W \cos \alpha + T \cos \theta - U) \tan \Phi / W \sin \alpha - T \sin \theta$$

$$U = \gamma_w \cdot H_w^2 / 4 \sin \alpha$$



# EQUILÍBRIO LIMITE PLANOS PARALELOS AO TALUDE (COM FENDA DE TRACÇÃO)



$$FS = \frac{cA + (W(\cos\Psi_s - \alpha\sin\Psi_s) - U - V\sin\Psi_s + T\cos\theta)\tan\phi}{W(\sin\Psi_s + \alpha\cos\Psi_s) + V\cos\Psi_s - T\sin\theta}$$

Eq. (6)

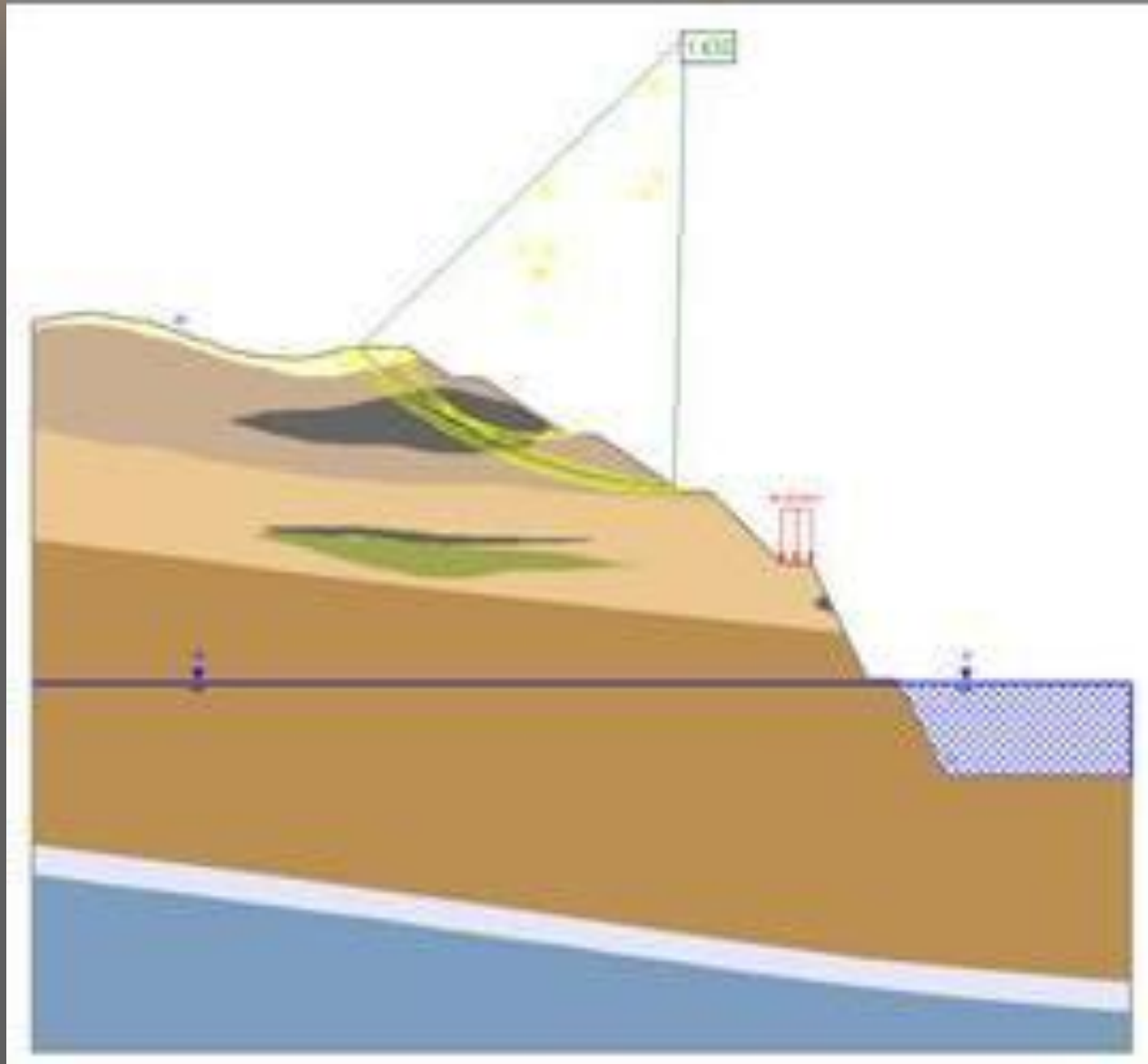
onde:

$$z = H + b \tan\Psi_s - (b + H \cot\Psi_s) \tan\Psi_p \quad (7)$$

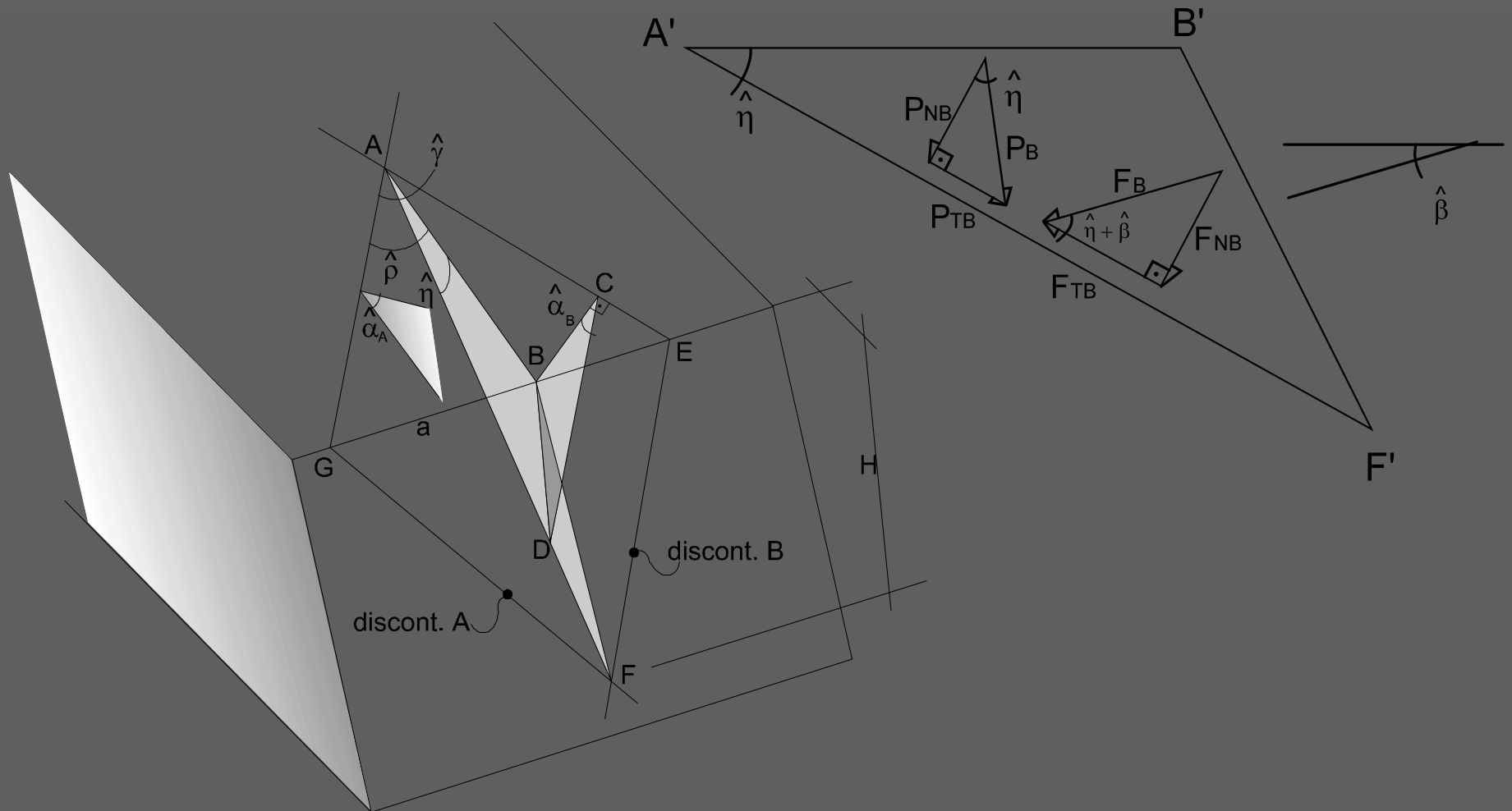
$$A = (H \cot\Psi_s + b) \sec\Psi_p \quad (8)$$

$$W = 0.5 \gamma (H^2 \cot\Psi_s X + bHX + bz) \quad (9)$$

# PROGRAMA SLIDE



# ANALISE TRIDIMENSIONAL DE CUNHA DE ROCHA E DIMENSIONAMENTO DE ATIRANTAMENTO

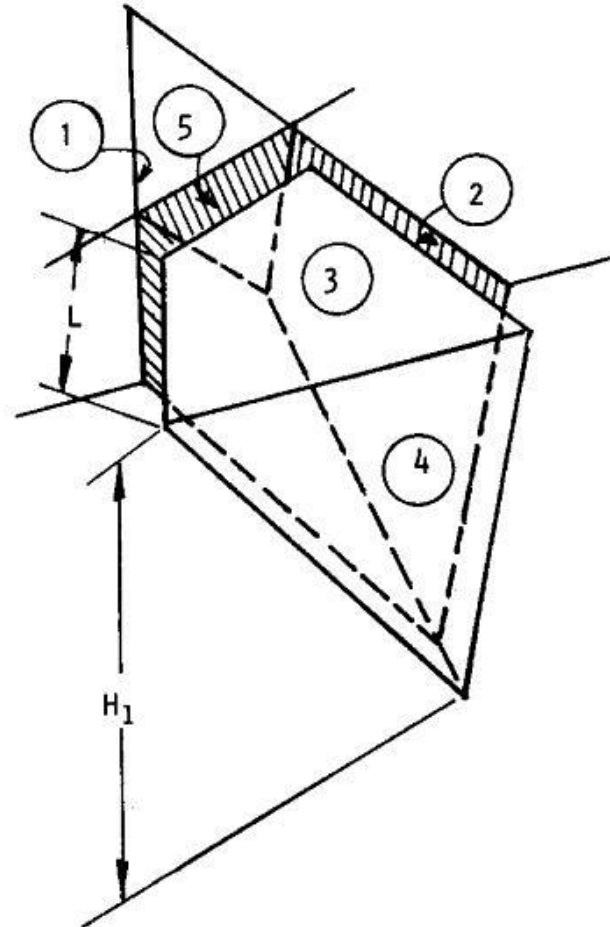




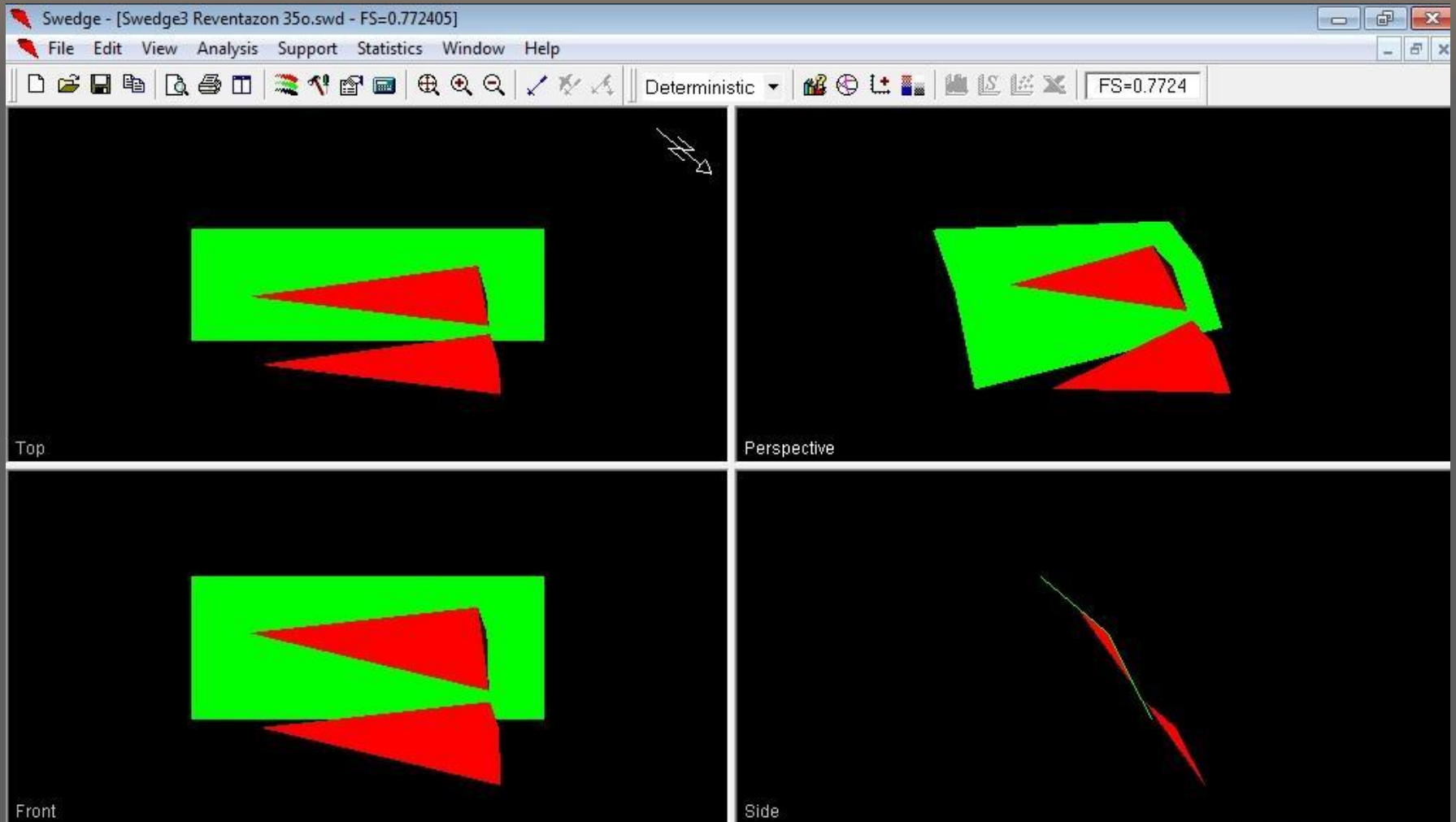
# PROGRAMA SWEDGE

## LEGEND

- 1, 2 = Failure planes (2 intersecting joint sets)
- 3 = Upper ground surface
- 4 = Slope face
- 5 = Tension crack
- H<sub>1</sub> = Slope height (vertical distance) referred to plane 1
- L = Distance of tension crack from crest, measured along the trace of plane 1.



# PROGRAMA SWEDGE



**MUITO OBRIGADO**