Lecture 3

Anticipating and Solving Problems with Excavations and Slopes in Bimrocks

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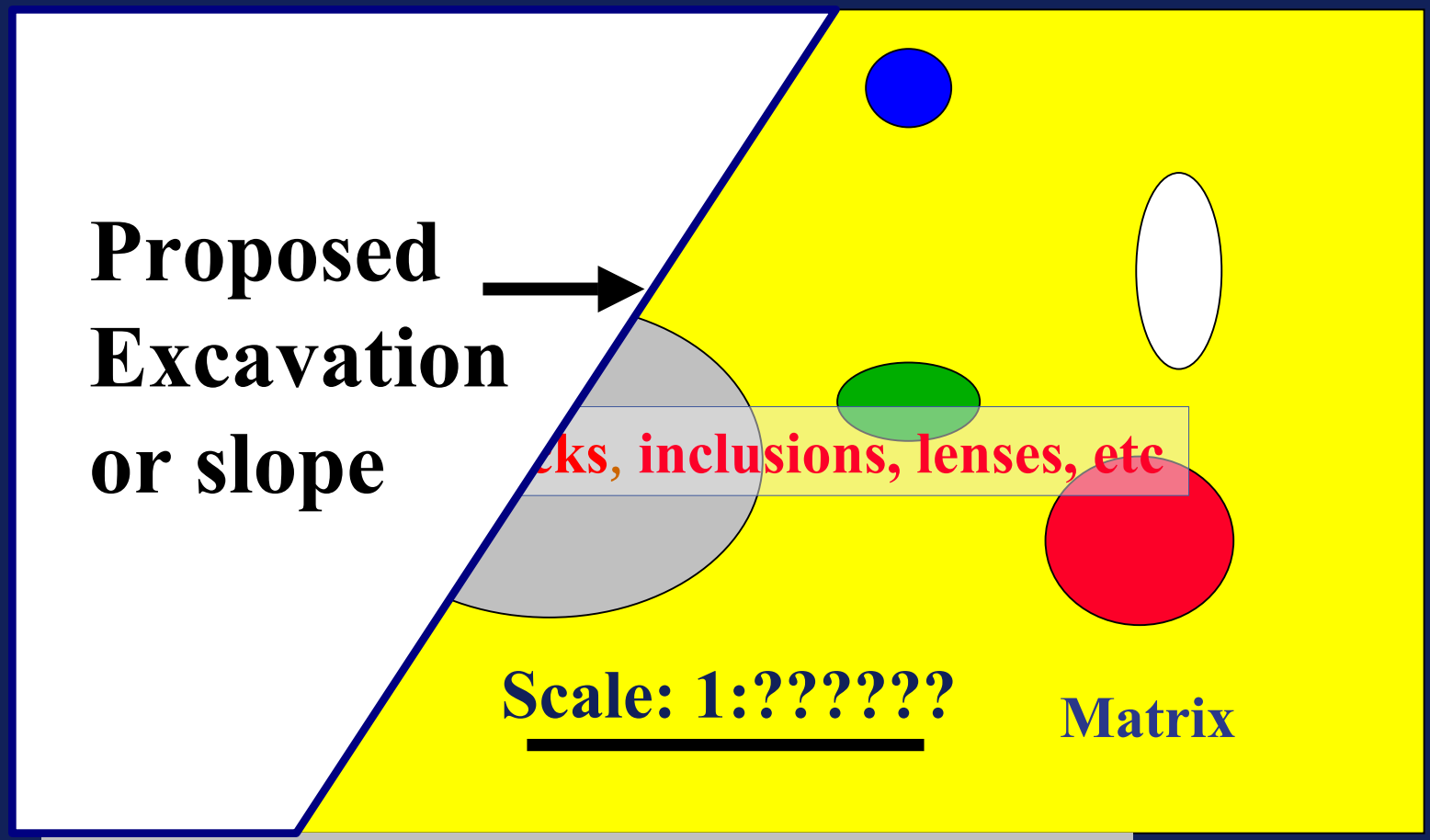
Bimrocks Short Course, Haceteppe Univ, Ankara,

June 21, 2004

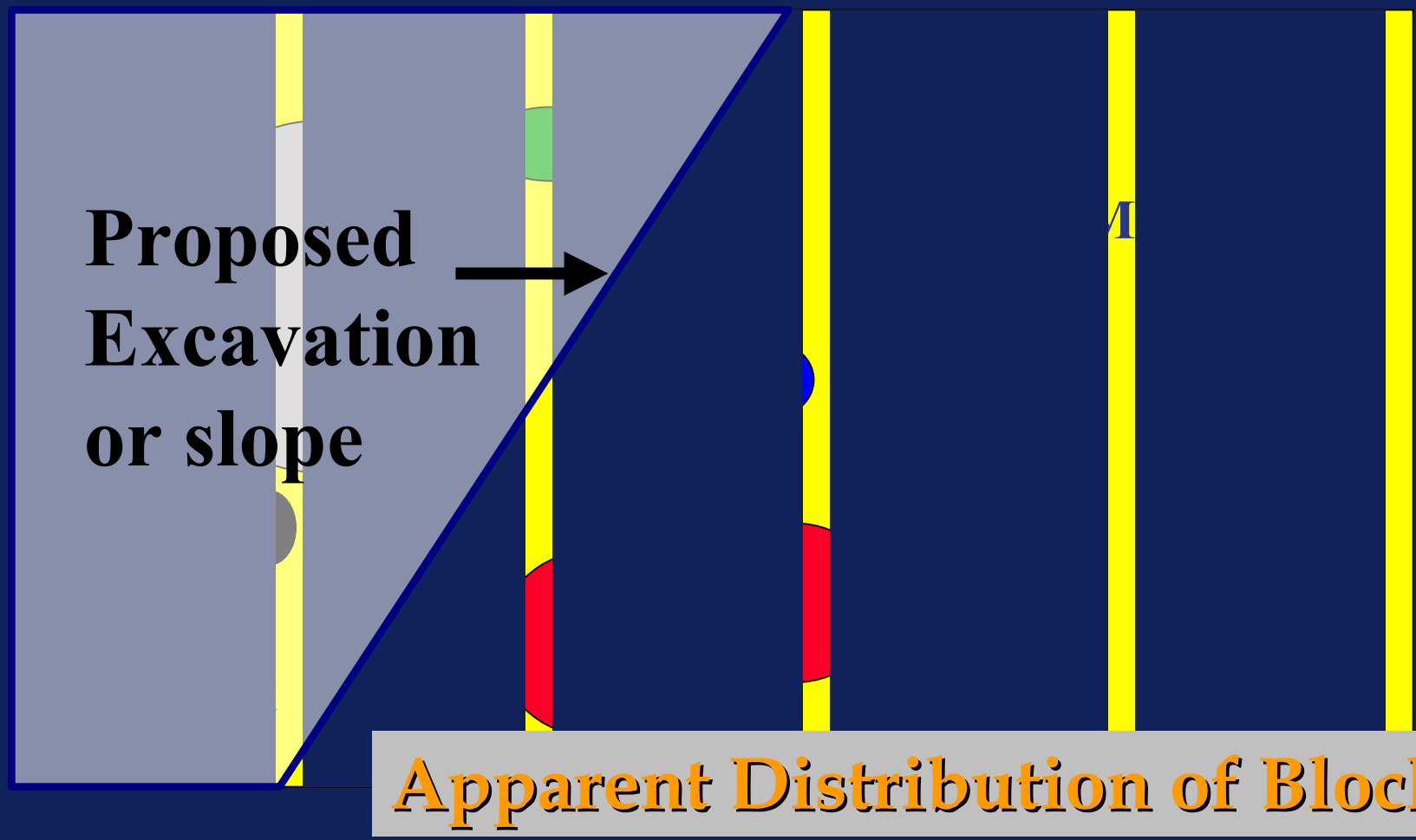
BIG CONCLUSION 1:
Remember this picture!!!



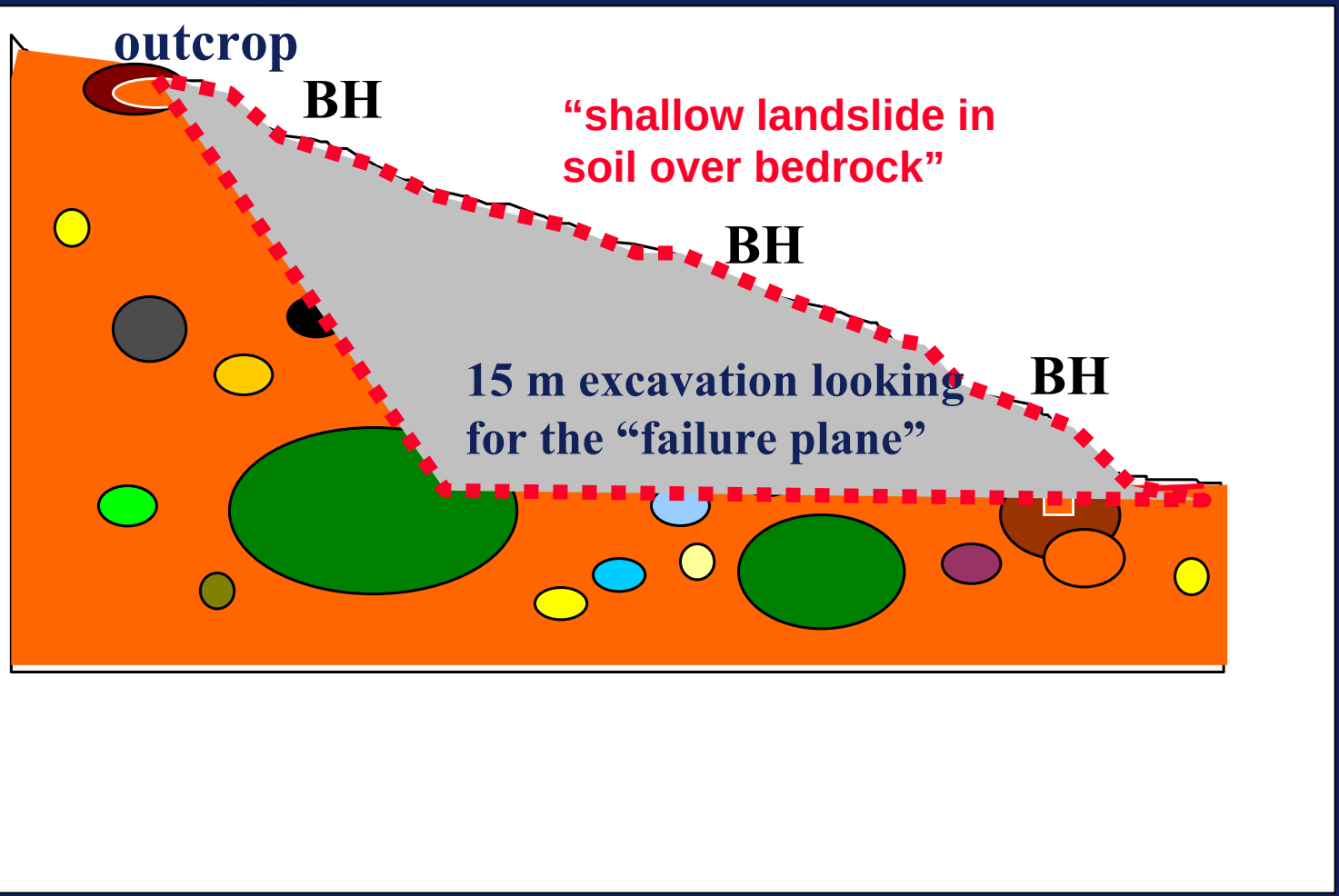
Actual Distribution of Blocks

Medley, 2000

BIG CONCLUSION 2:
Remember this picture as well!!!

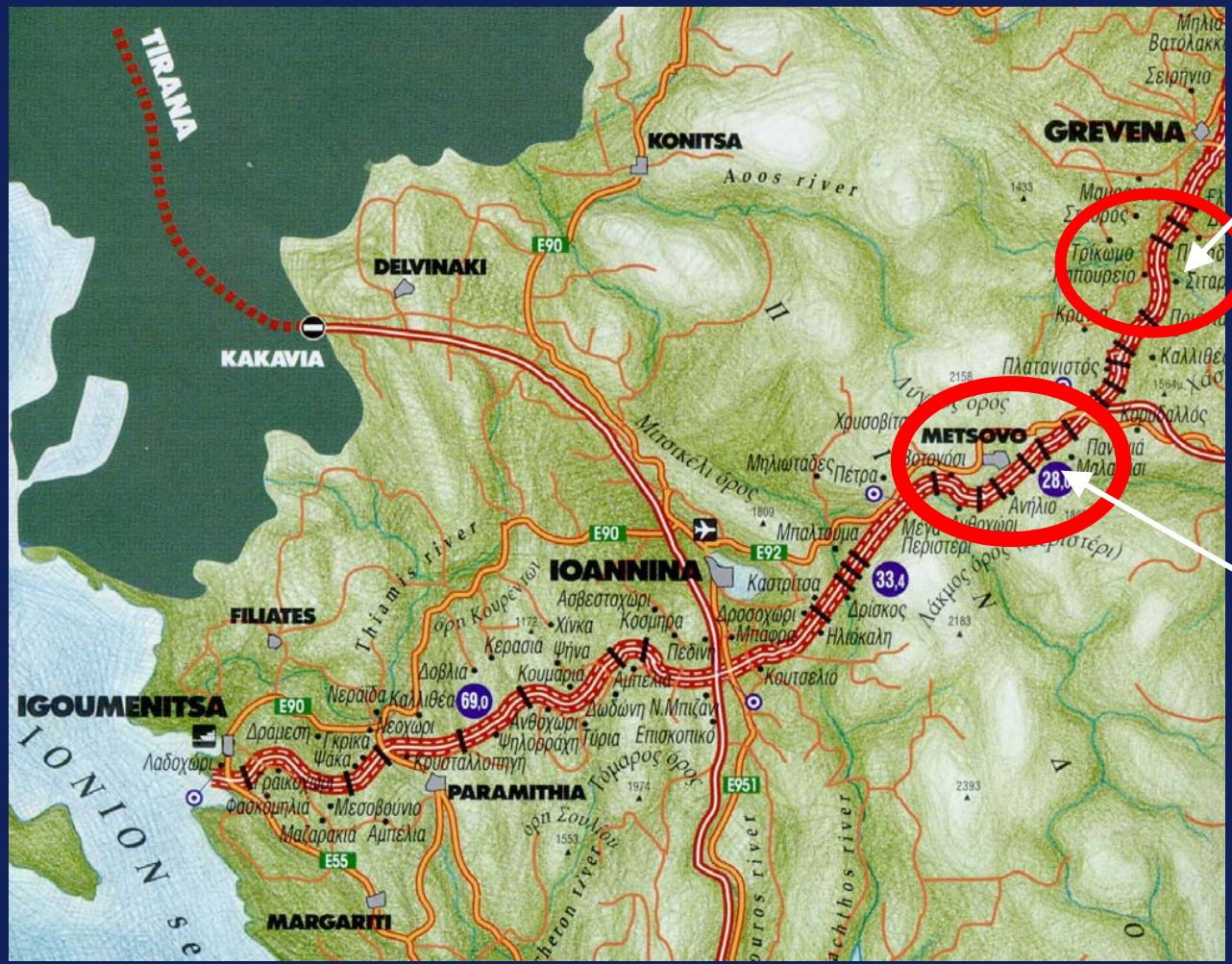


Mischaracterization of bimrocks for slope constructions = “mi$ery”



Case Study

Egnatia Motorway, Greece



Tunnels in a tectonic melange and olistostrome

Tunnels in thrust duplexes

Slope Instability Case Study

Egnatia Motorway, Greece: *Malakasi Section*

- Alpine forearc region, containing **chaotic rock mass** of predominantly shale, sandstone, siltstone, limestone and ophiolitic lithologies
- The chaotic deposits include **olistostromes** and **tectonic melanges**, which characteristically contain a chaotic arrangement of competent blocks (limestone and ophiolitic olistoliths and/or phacoids) in an irregularly sheared weak matrix consisting of shale, sandstone, siltstone and gouge
- This chaotic rock mass from different geological environments can be characterized from the engineering perspective as **„block-in-matrix rocks“**

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Case Study: Egnatia Motorway, Greece

Limestone Olistolith (Block) Embedded in an Irregularly Foliated Matrix of Shale, Siltstone and Sandstone

Case Study: Egnatia Motorway, Greece

Limestone Olistolith Embedded in an Irregularly Foliated Matrix of Shale, Siltstone and Sandstone

Slope Excavated for Motorway

(One-slide excursion halfway around the world to see similar block in California)

Photo: Ed Medley

Case Study: Egnatia Motorway, Greece

Development of Landslides Caused by the Construction of the Motorway

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Case Study: Egnatia Motorway, Greece

Damaged Pre-Cut of the Tunnel M2 West Portal

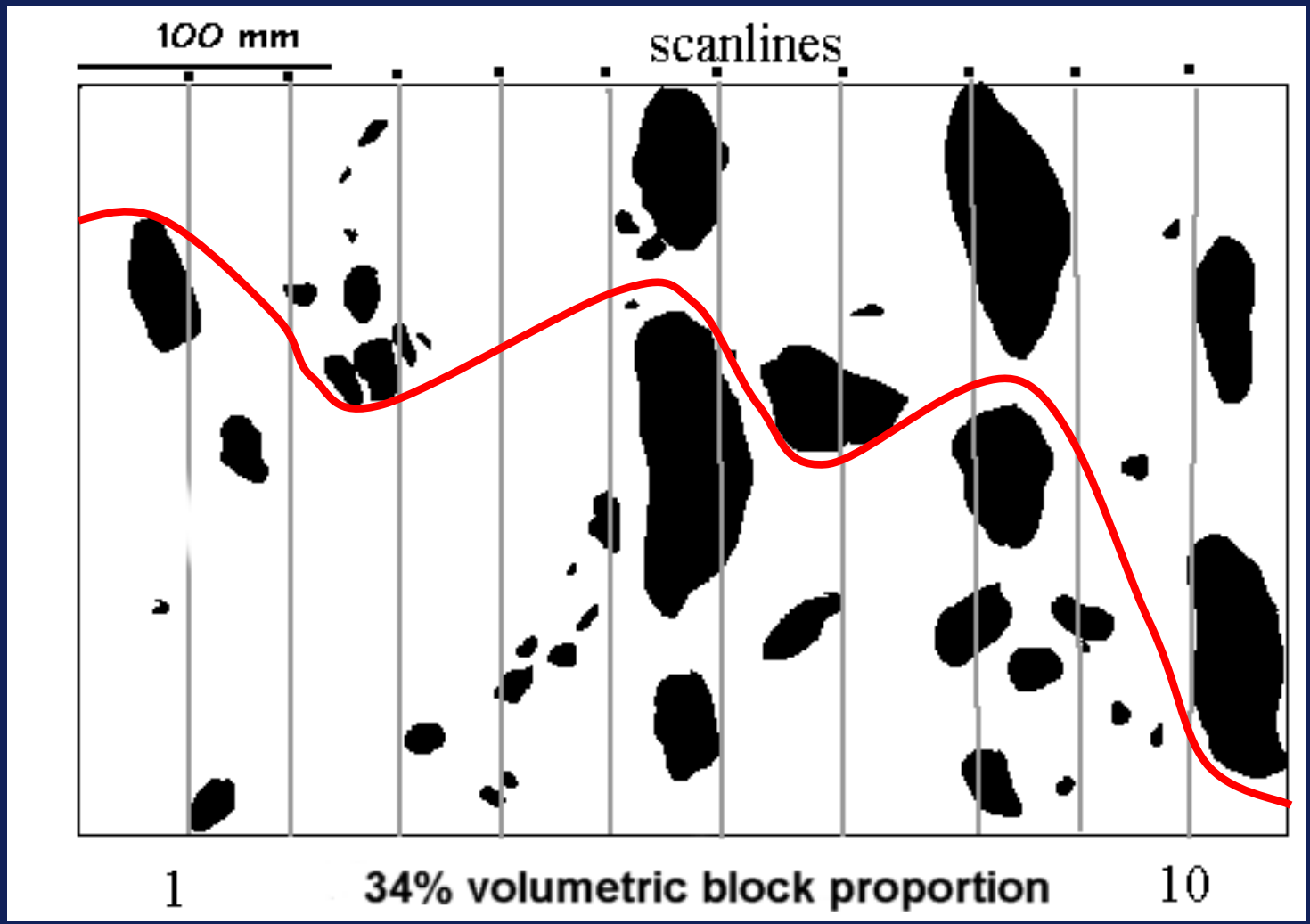
Effects on slope stability of TORTUOSITY of failure surfaces negotiating around blocks

Failed physical model melanges

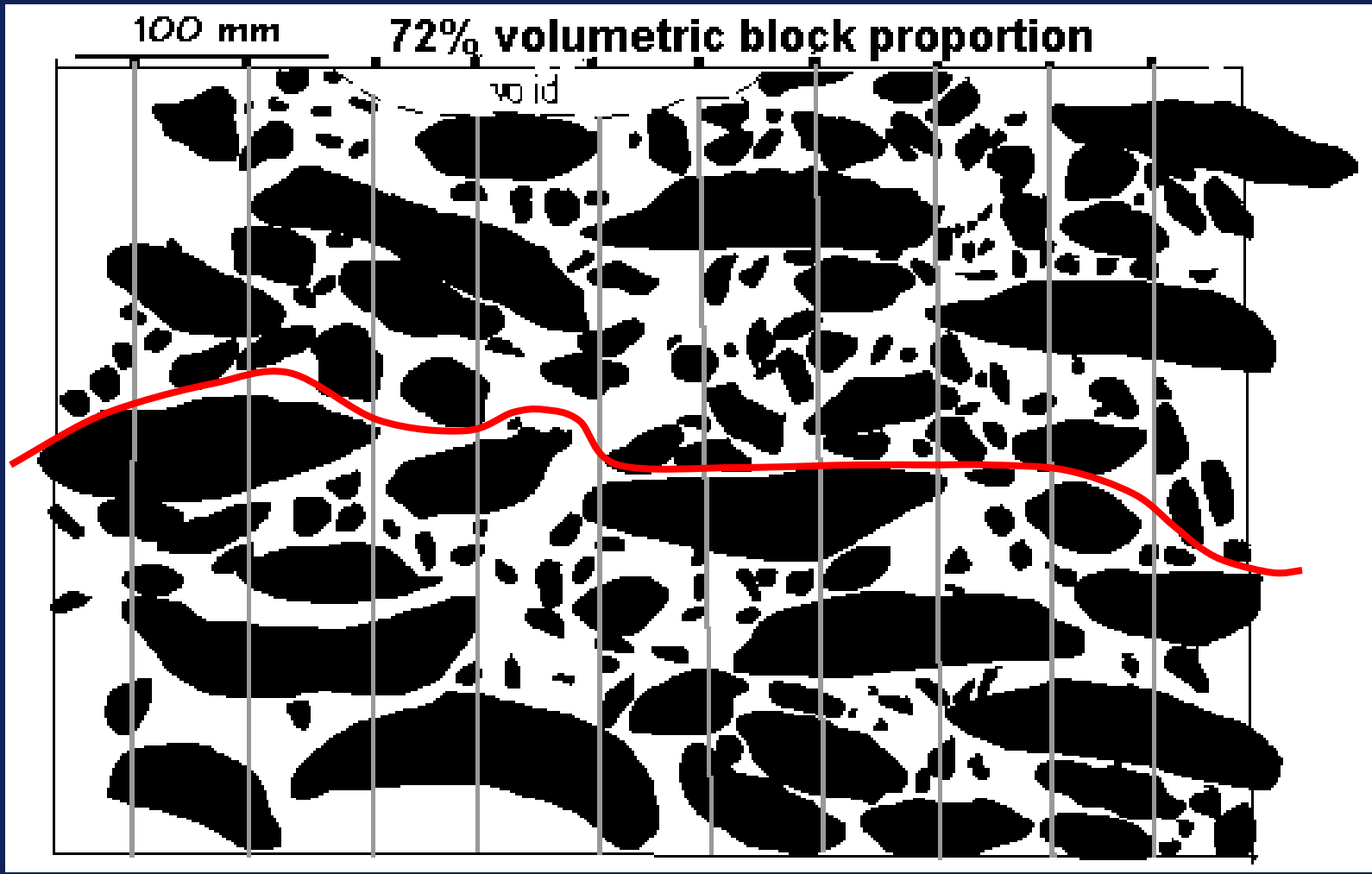
150 mm diameter Tx specimens (Lindquist, 1994)

failure surfaces tortuously negotiate blocks

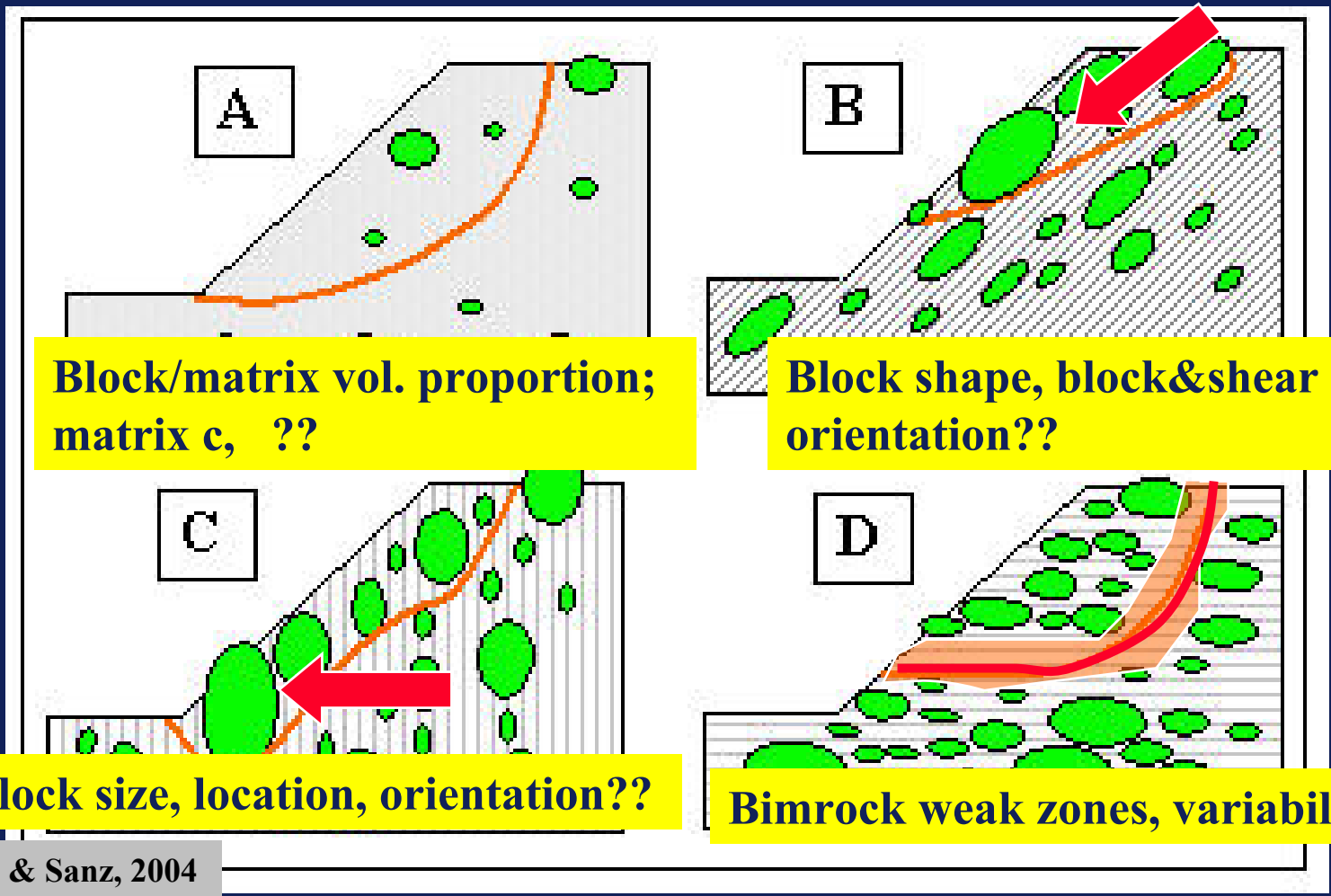
Tortuosity of failure surfaces influenced by low block proportion and vertical orientation



Tortuosity influenced by high proportion but horizontal orientation

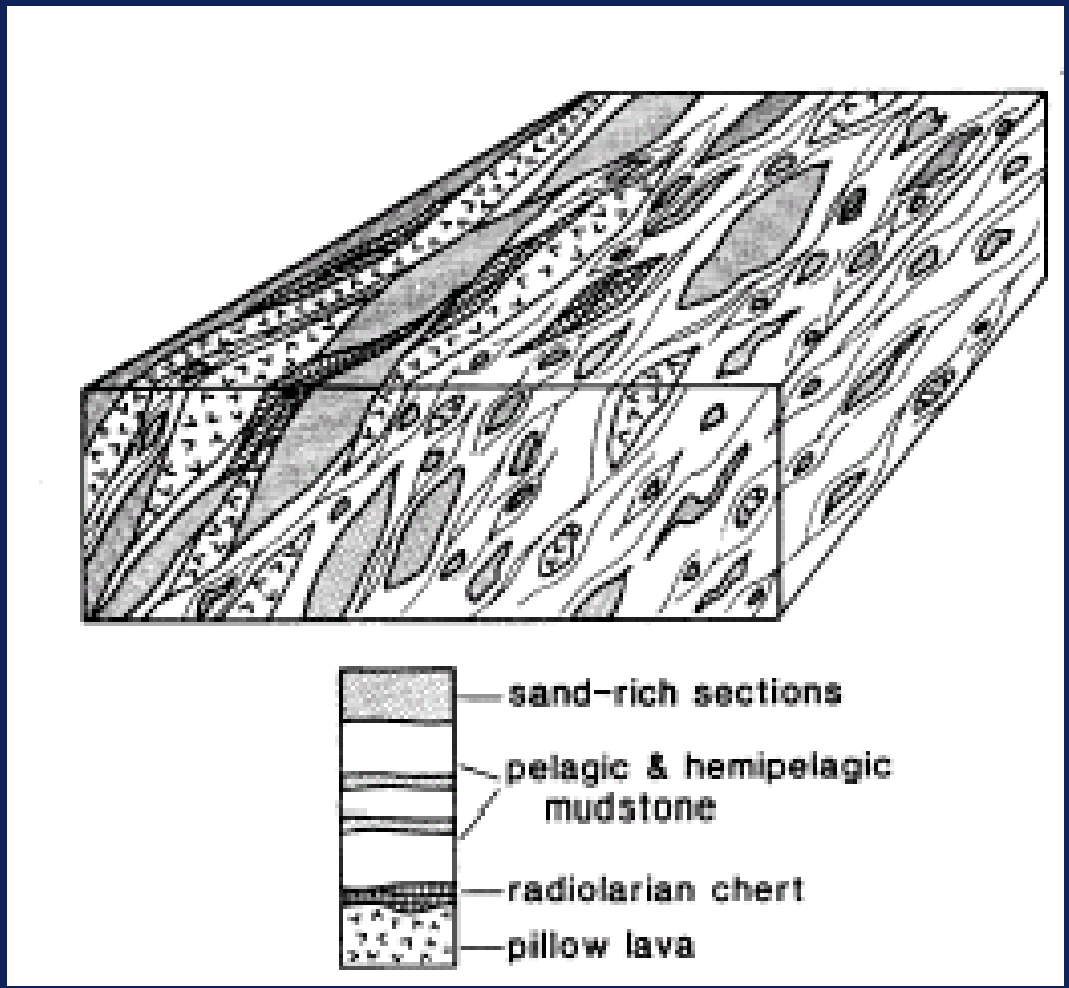


What are the influences on tortuosity and slope stability in bimrocks?



Medley & Sanz, 2004

Block orientation in bimrocks



Cowan, 1985

Mapping of slopes (Bolu Tunnel, Turkey)

Typical Melange Showing Diverse Elongate Blocks and Irregular Foliated Matrix (S-M-C-Cataclasites)

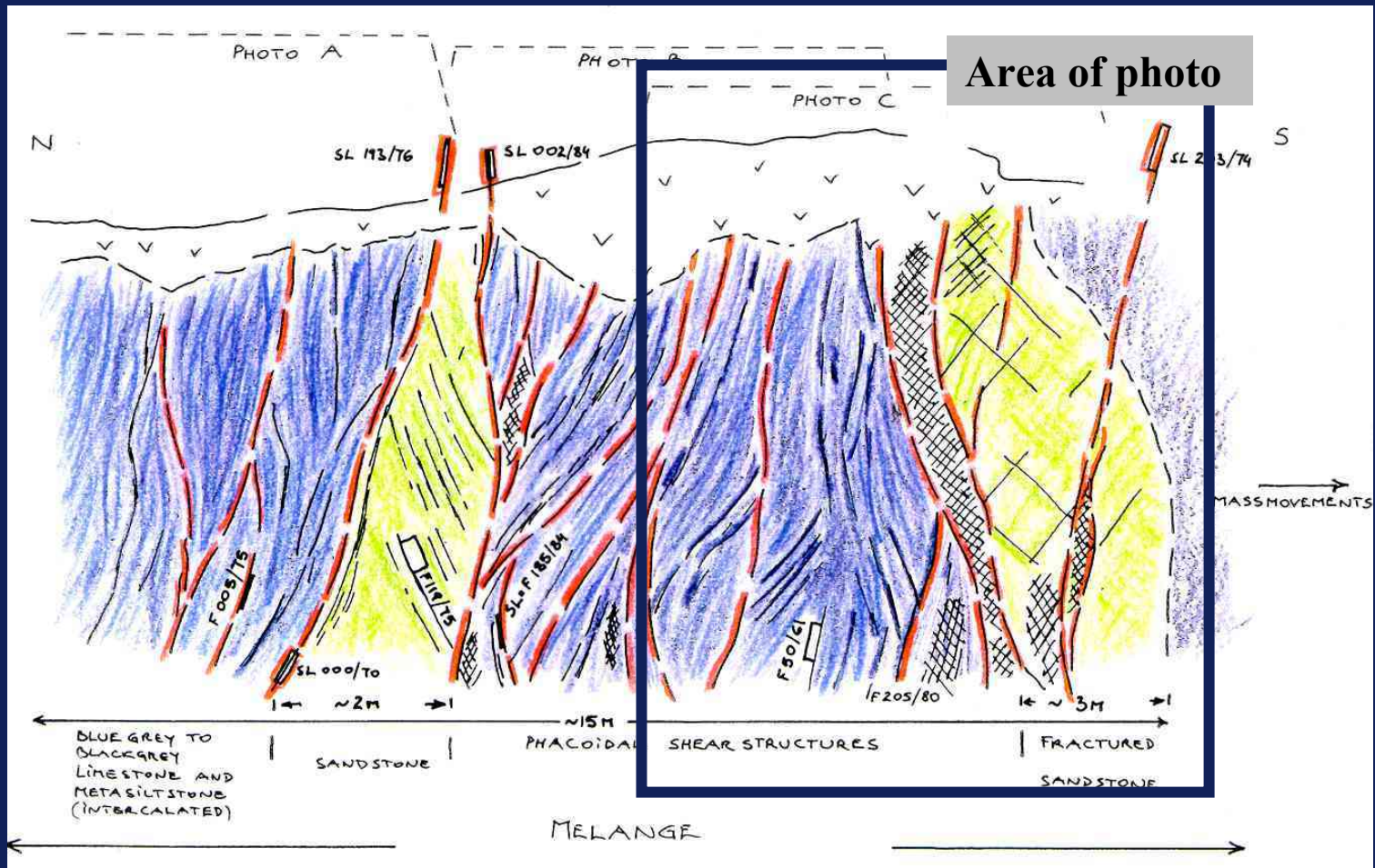
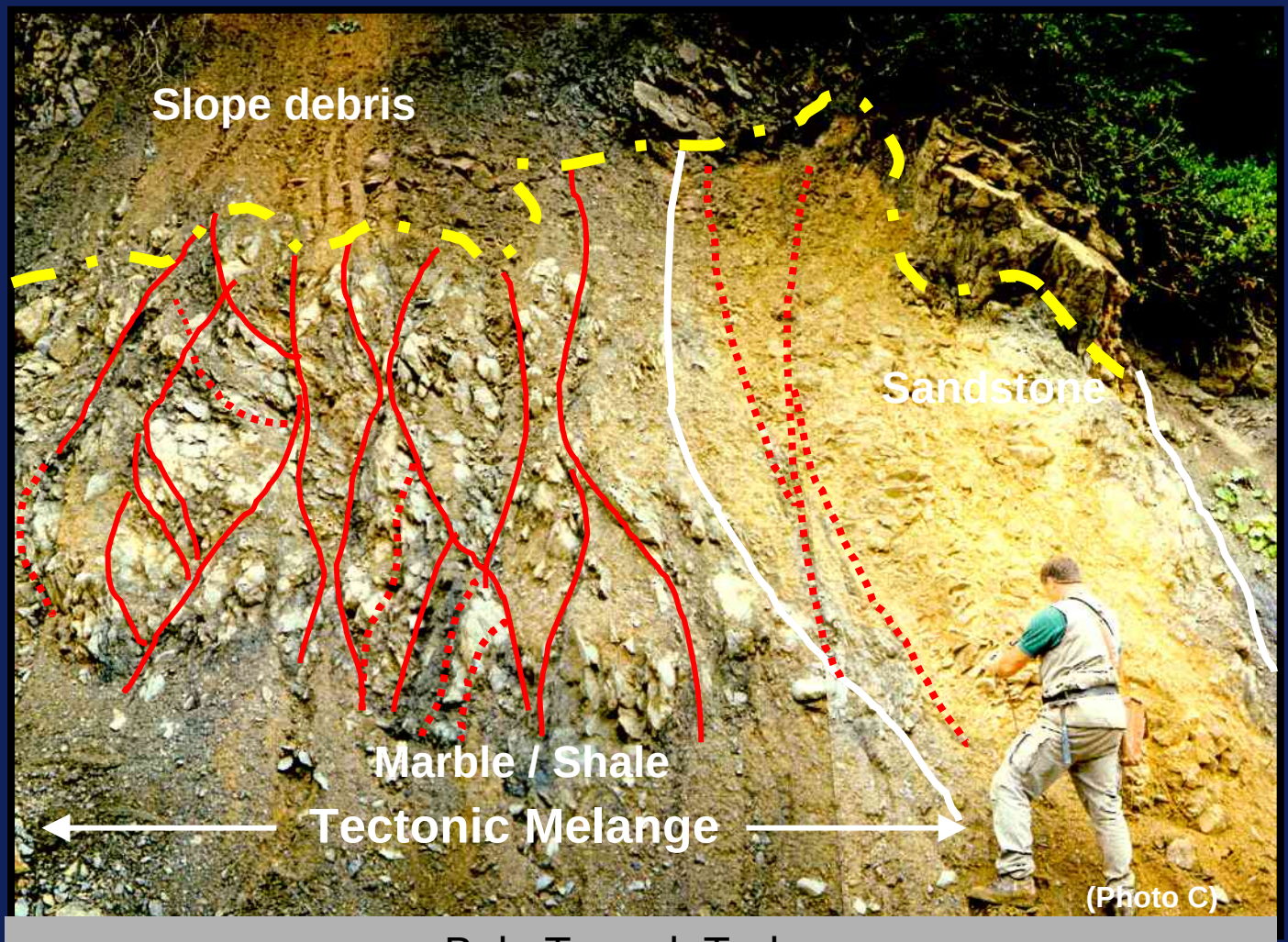


Photo of area in previous sketch (Bolu Tunnel)

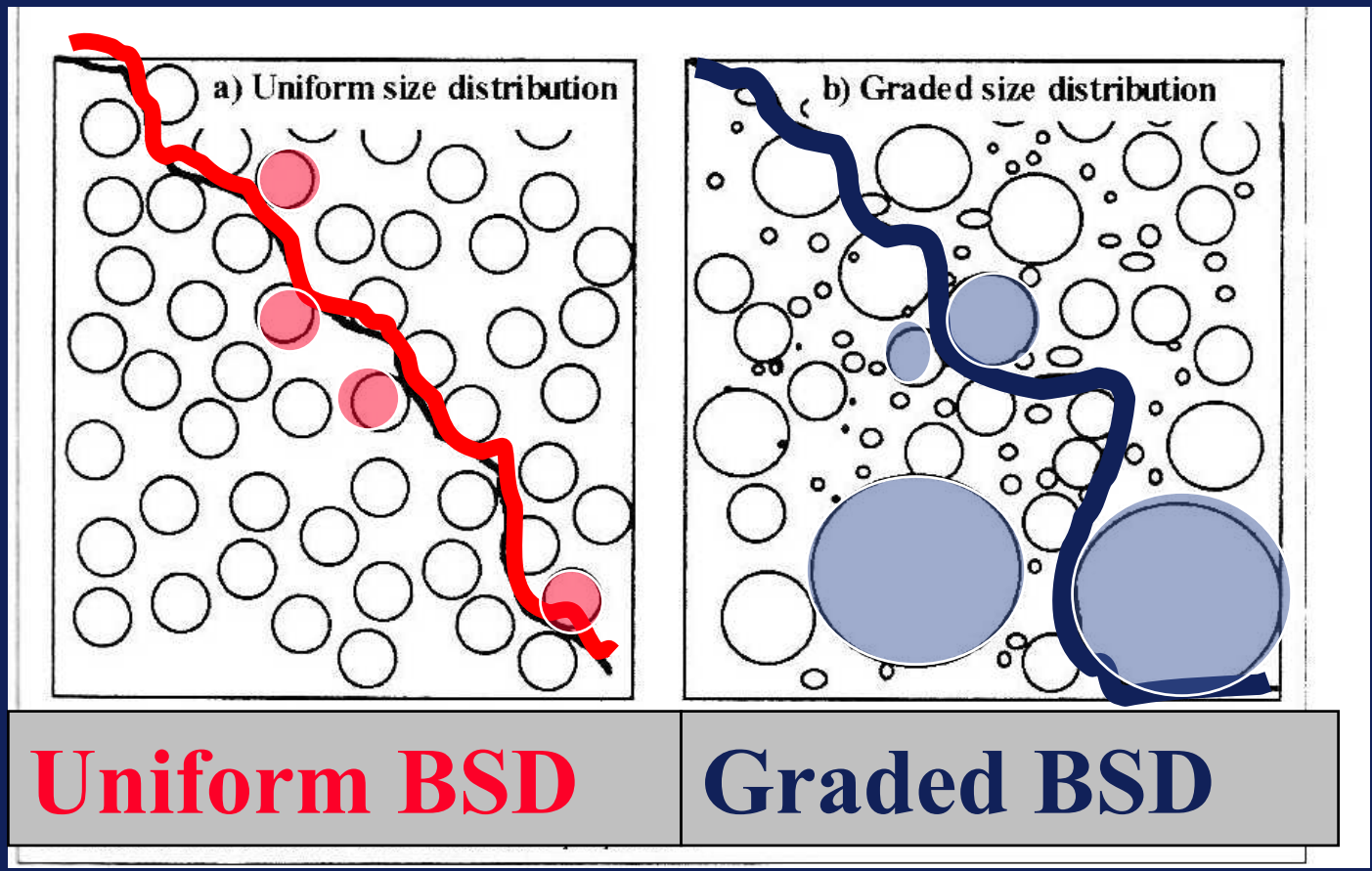
Typical Melange Showing Diverse Elongate Blocks and Irregular Foliated Matrix (S-M-C-Cataclasites)



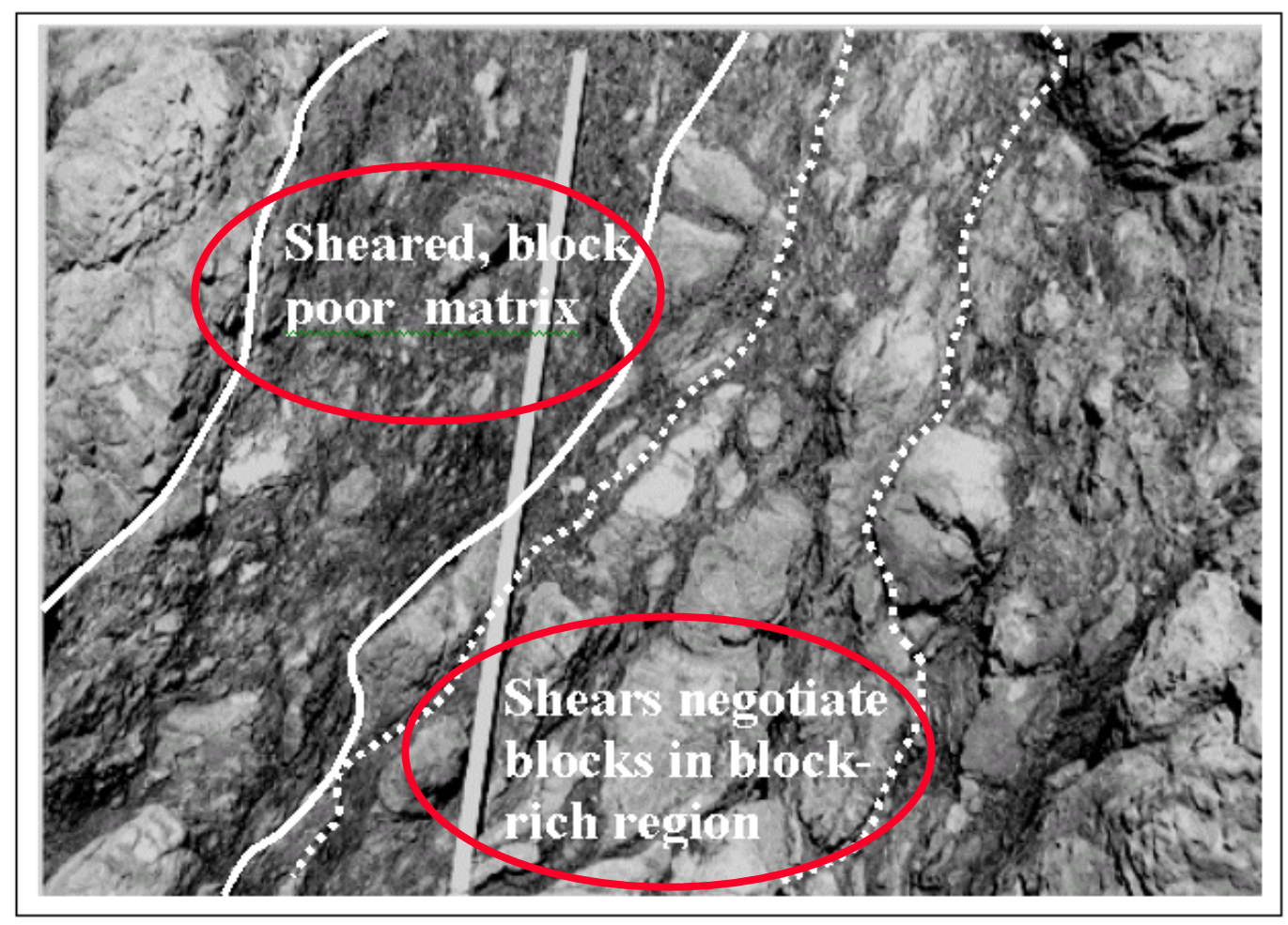
Bolu Tunnel, Turkey

 Consulting Geological Engineer emedley@bimrocks.com

Tortuosity influenced by Block Size Distribution (BSD) and block shapes



Zones of variable block proportion



Blocks stabilize melange at coast

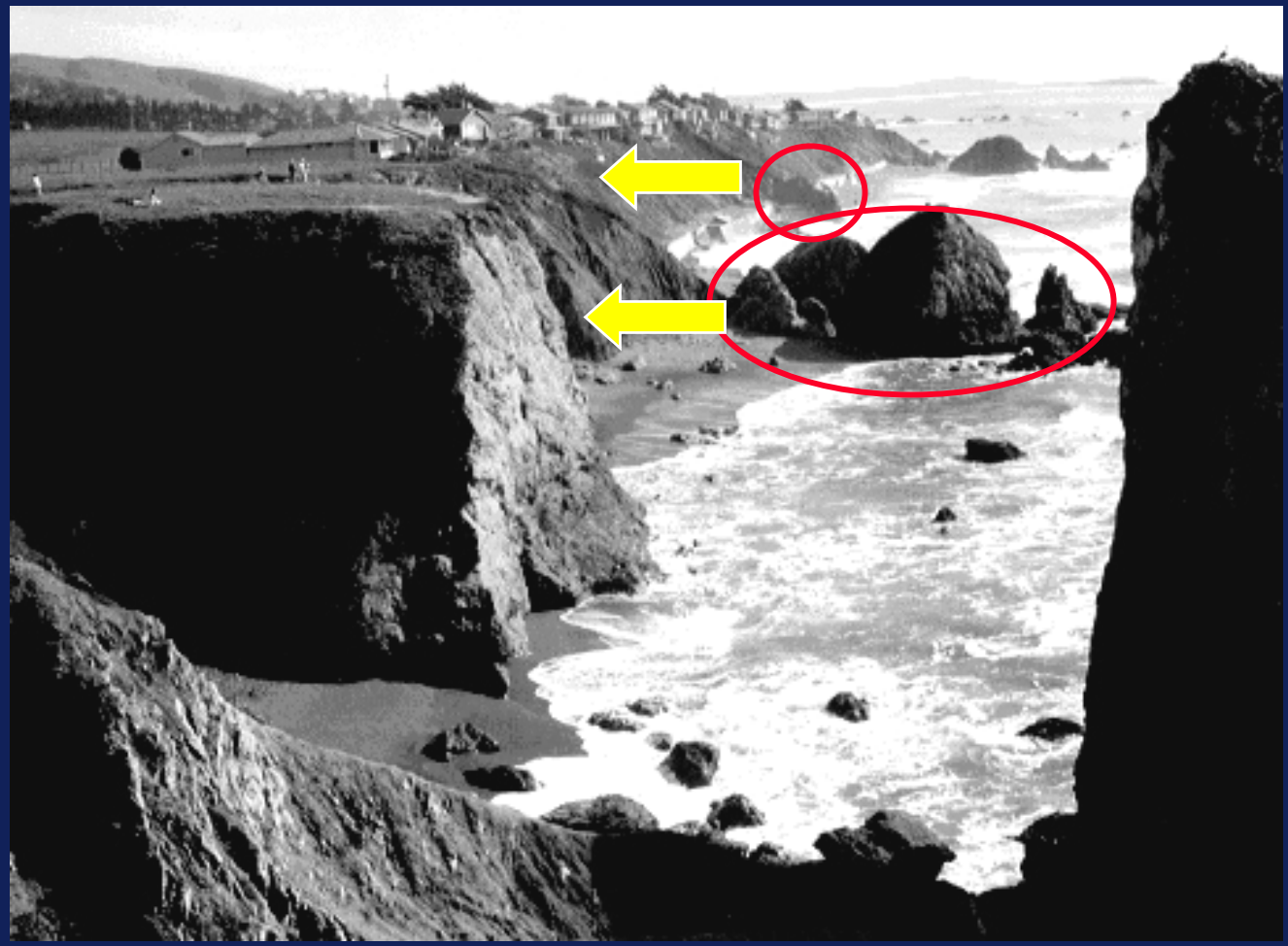


Photo Ed Medley

Landslide in Franciscan melange…

block-rich melange at toe resisted movement

..leading to back-facing scarps

Blocks added strength to matrix: but HOW MUCH??
(a motivation for some analysis..)

Photo: Ed Medley

Simple Investigation of effects of volumetric block proportion on slope Stability

(Medley& Sanz, 2003; in press)

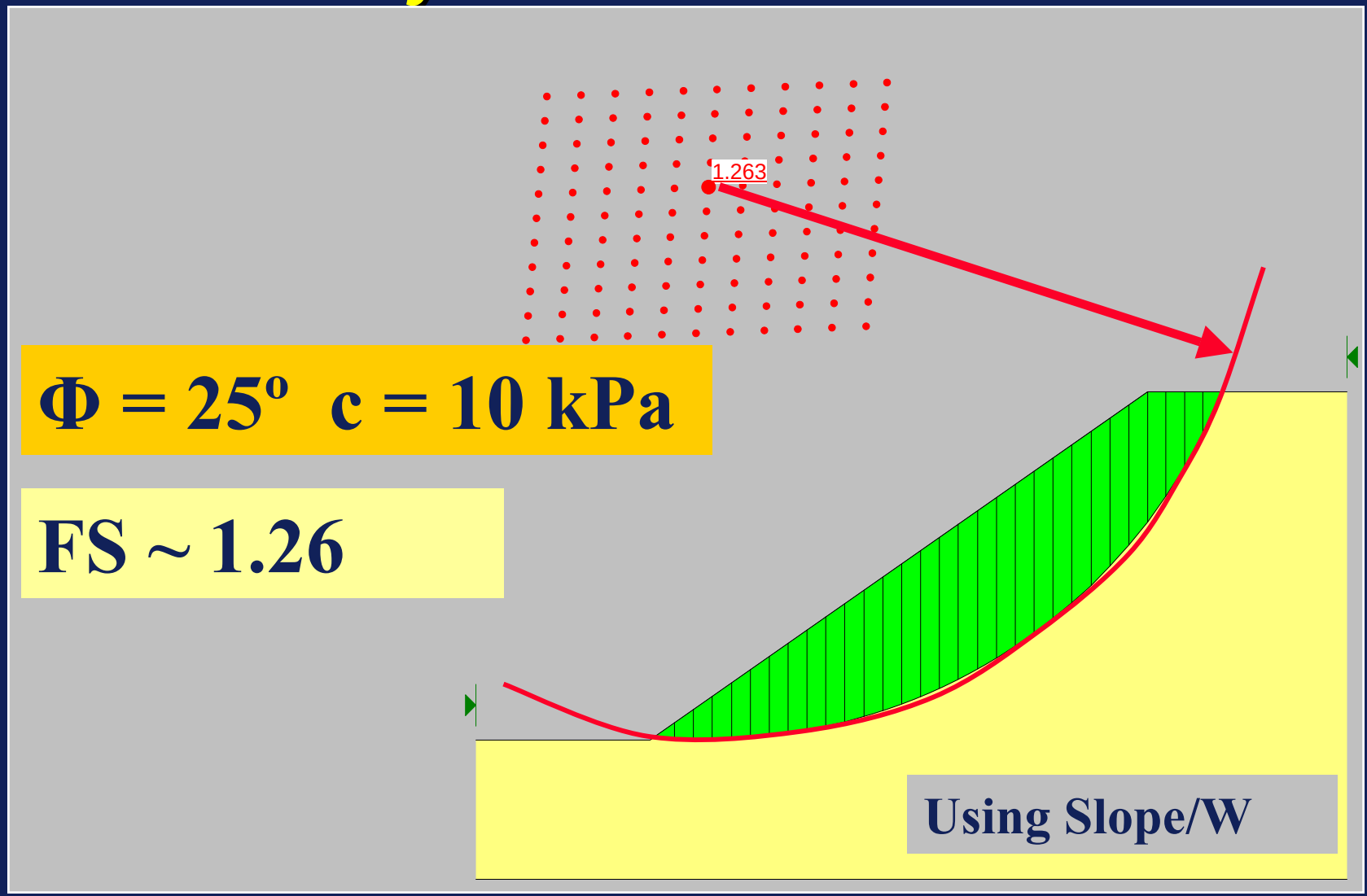
Analyses Assumptions

- matrix : $\Phi = 25^{o}$ c = 10 kPa (~200 psf)
- block strengths not considered
- no block/matrix contact strengths
- no water

Analyses Assumptions (cont.)

- BSD = part 2D Franciscan (~$2n^{1.3}$)
- horizontal block orientations
- random arrays of blocks
- Areal = Volumetric block proportions
- failure surfaces pass around blocks
- 2D analyses suffice (for now…)

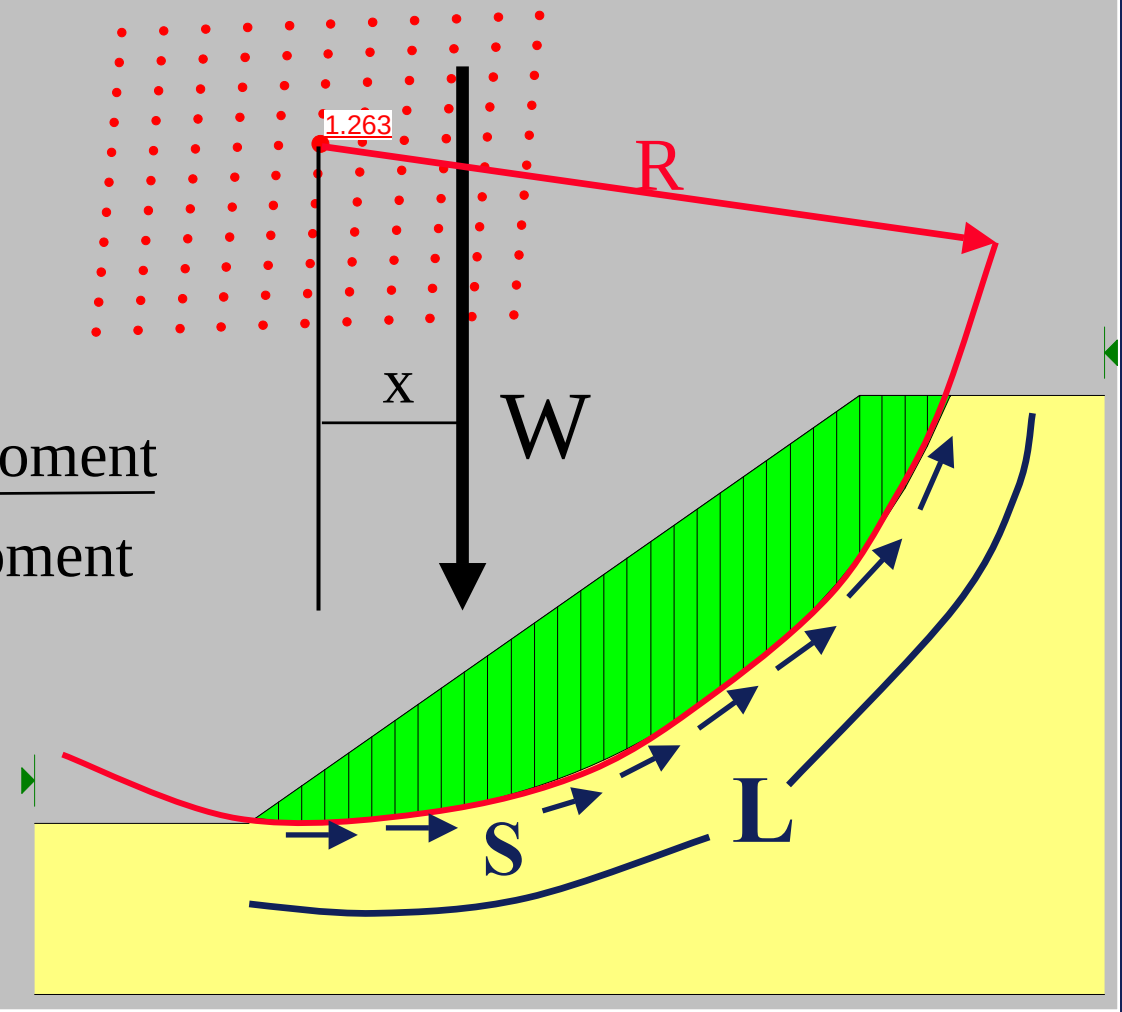
Matrix only: Critical failure surface



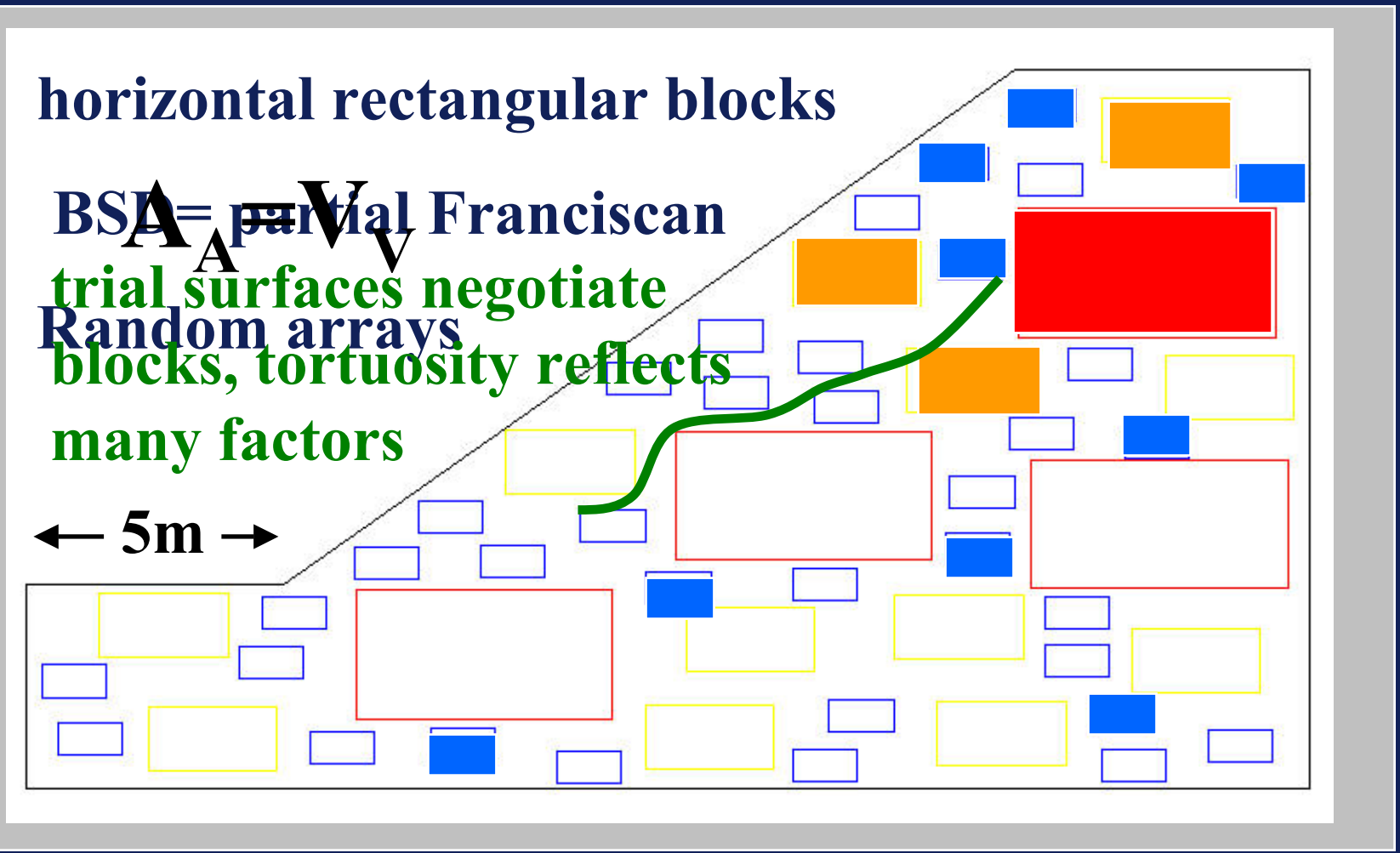
Factor of Safety (FS)

$$FS = \frac{\text{Resisting Moment}}{\text{Driving Moment}}$$

$$= \frac{\mathbf{RSL}}{\mathbf{Wx}}$$

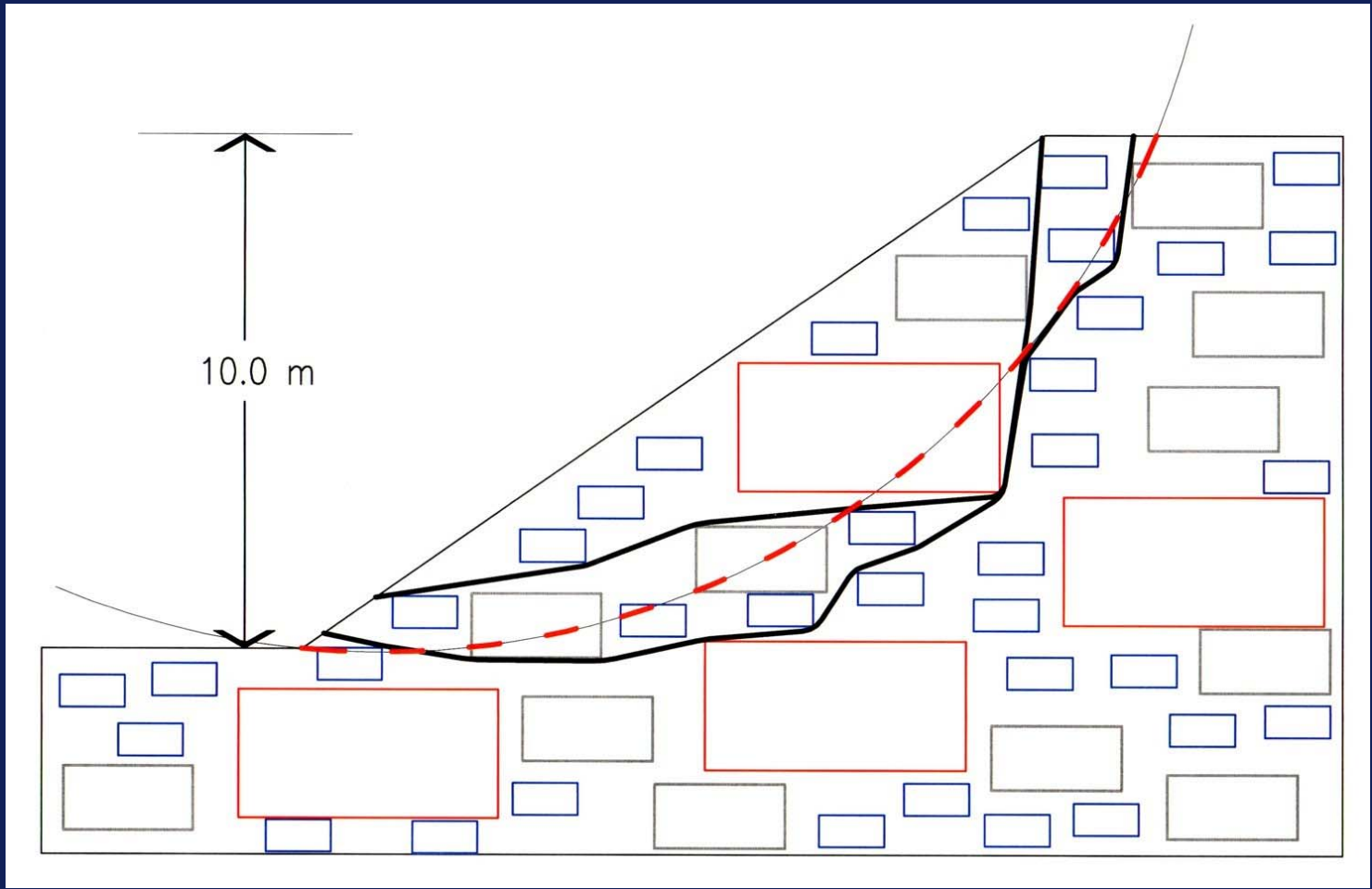


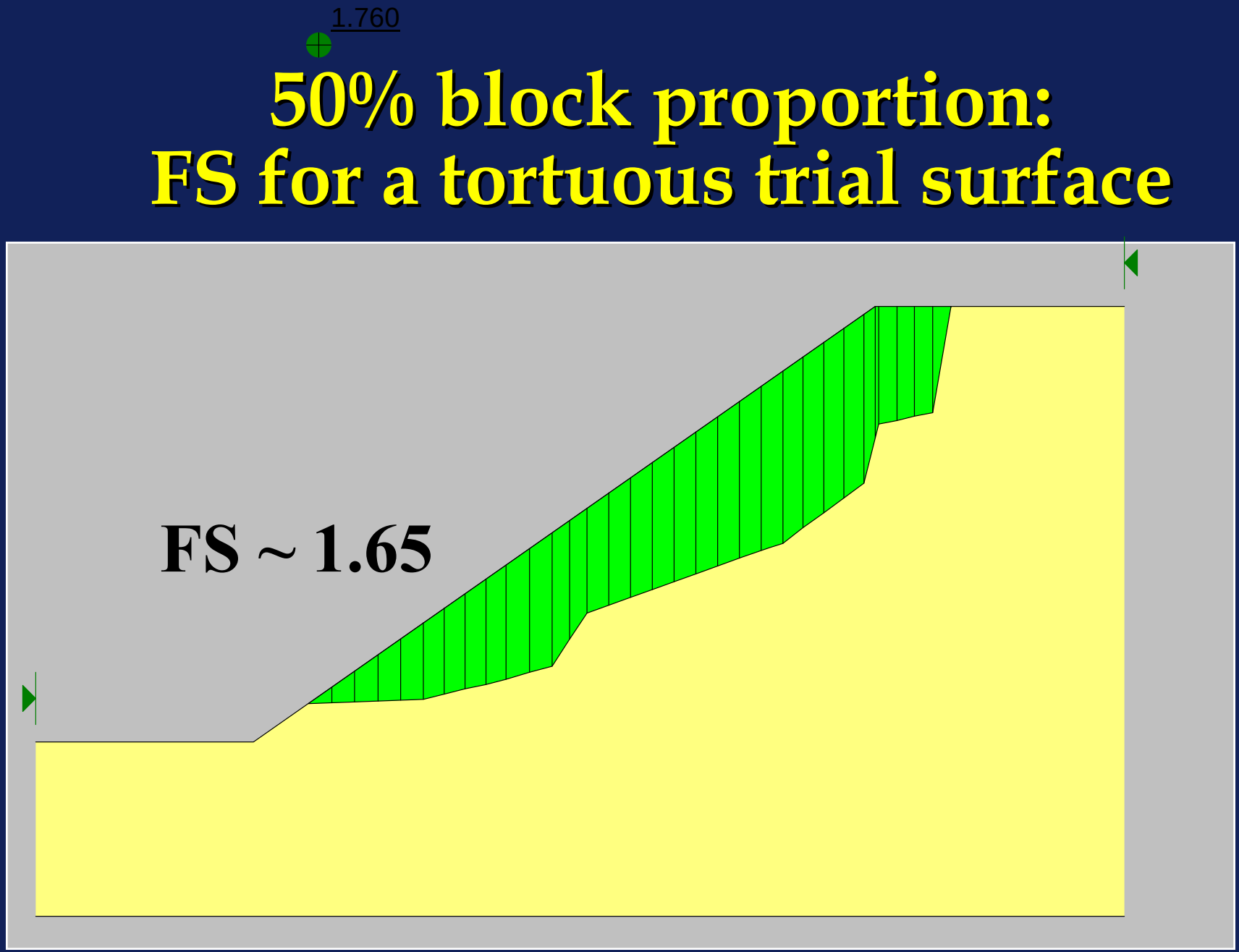
Model Assumptions



Simple random arrays of blocks

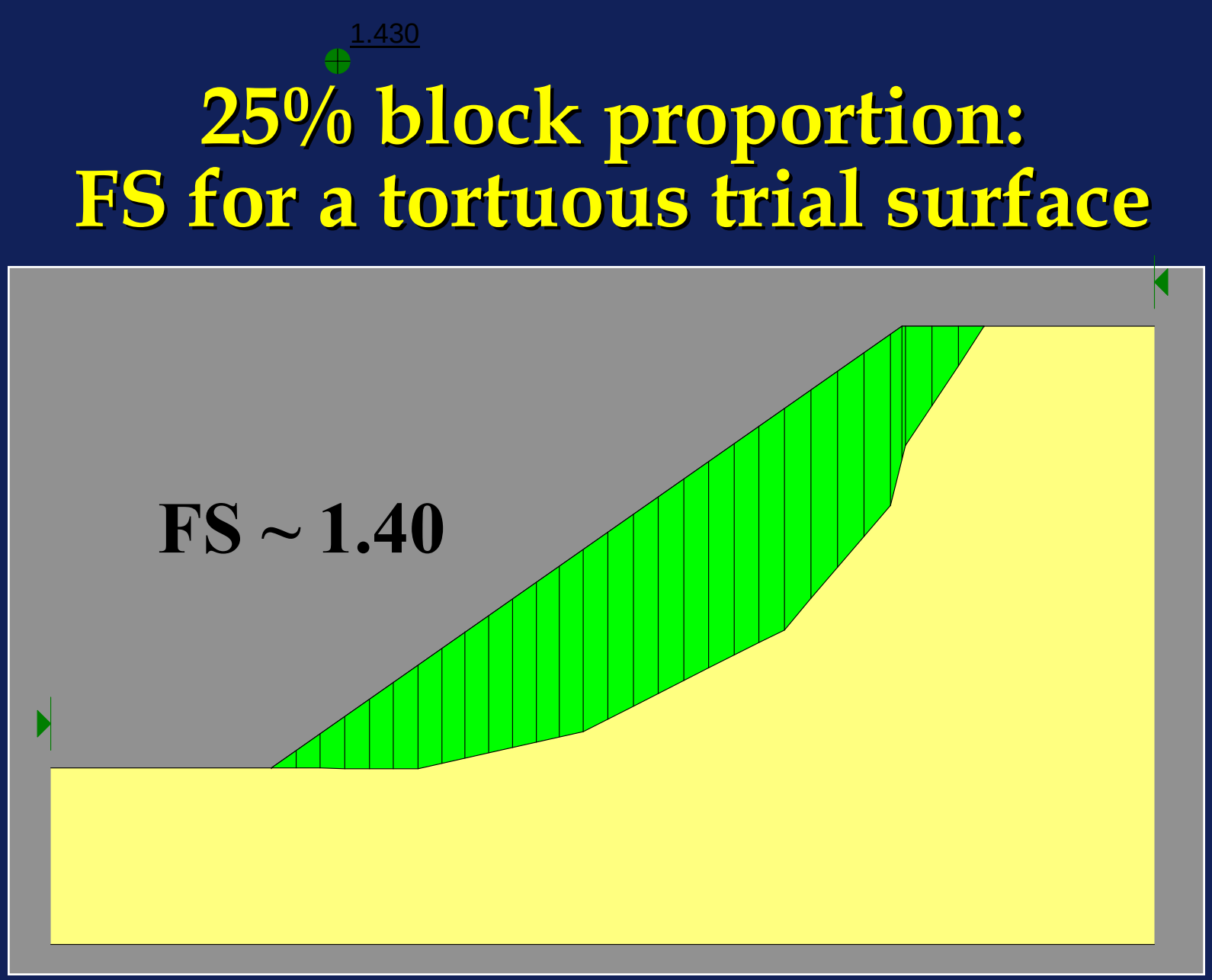
Tortuous trial surfaces





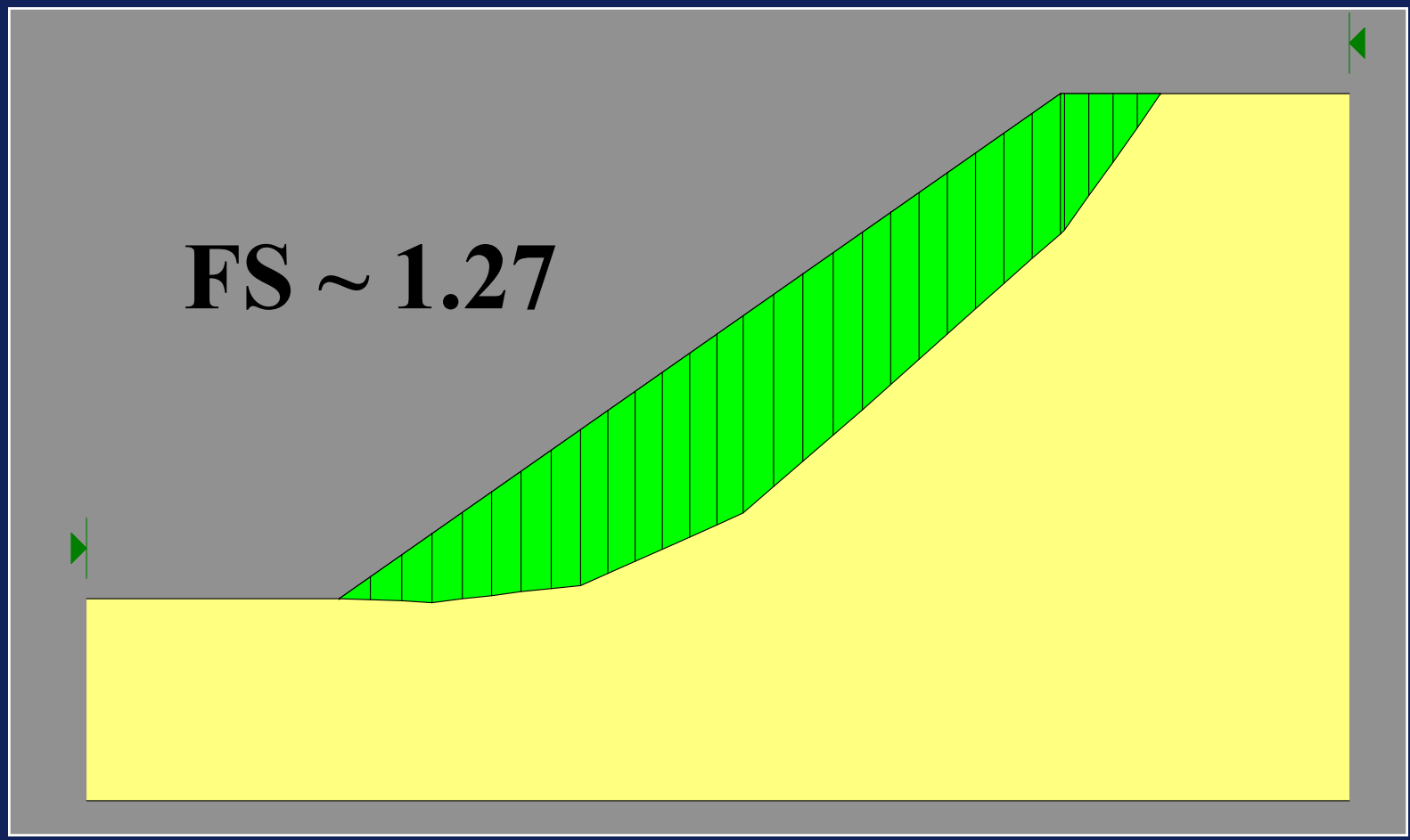
50% block proportion: FS for a tortuous trial surface

25% block proportion: FS for a tortuous trial surface

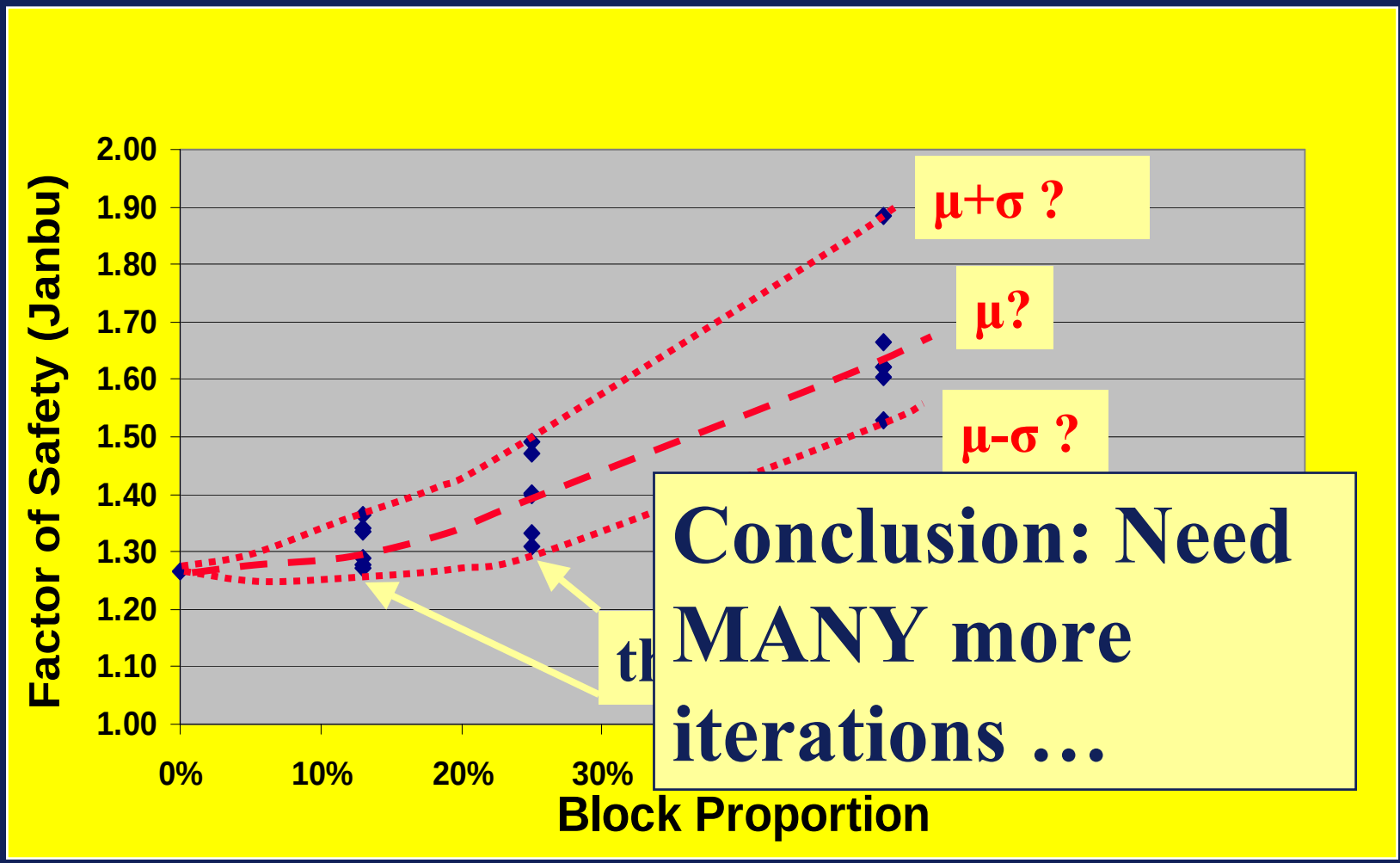


1.380

13% block proportion: FS for a tortuous trial surface



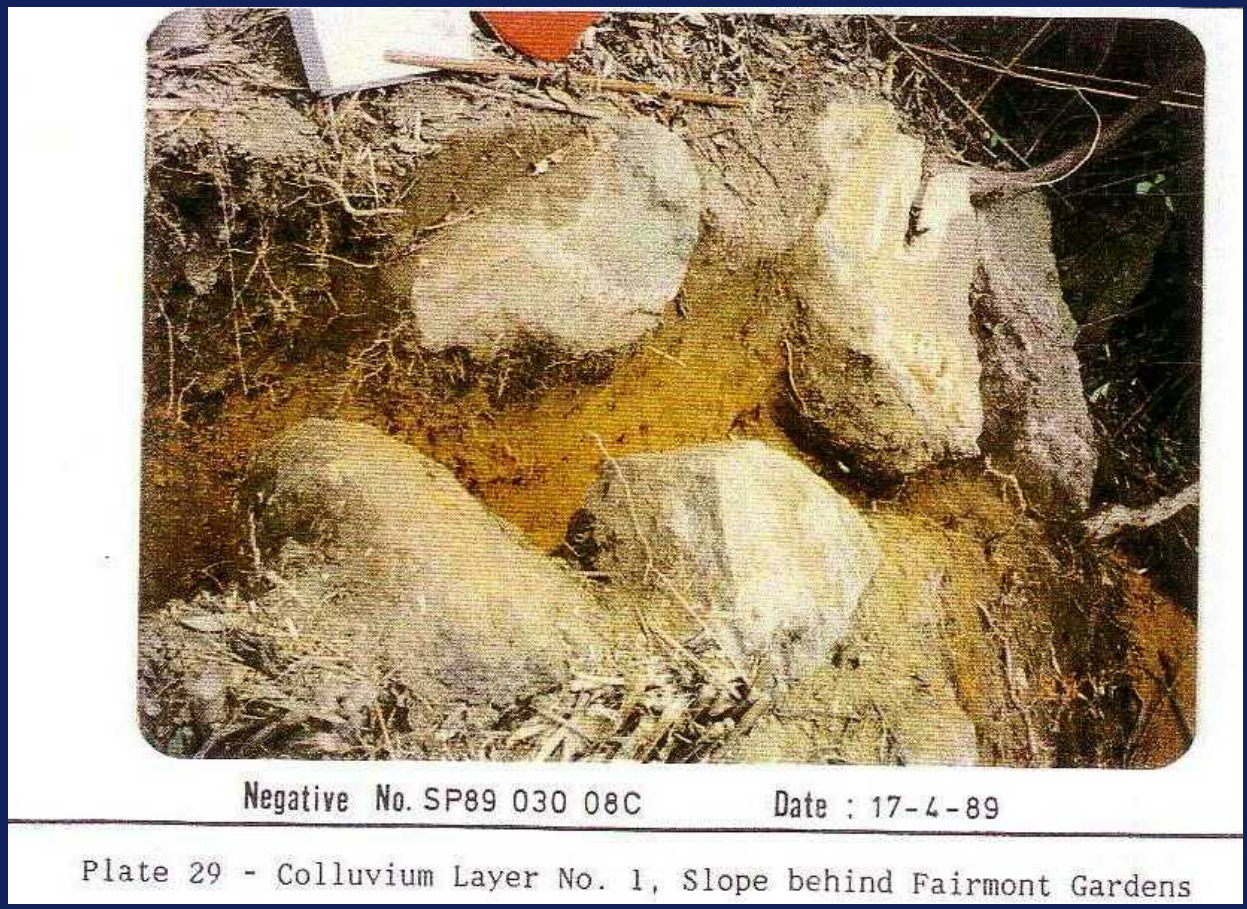
"First cut": Slope stability increases with block proportion



Shortcomings and good intentions

- Must incorporate block/matrix contact strengths
- Must generalize procedures for other block shapes, orientations, etc.
- Must perform Monte Carlo-type analyses
- Need 3D numerical modeling to incorporate blocks

Compare with Hong Kong experience of slope stability of Boulder Colluvium

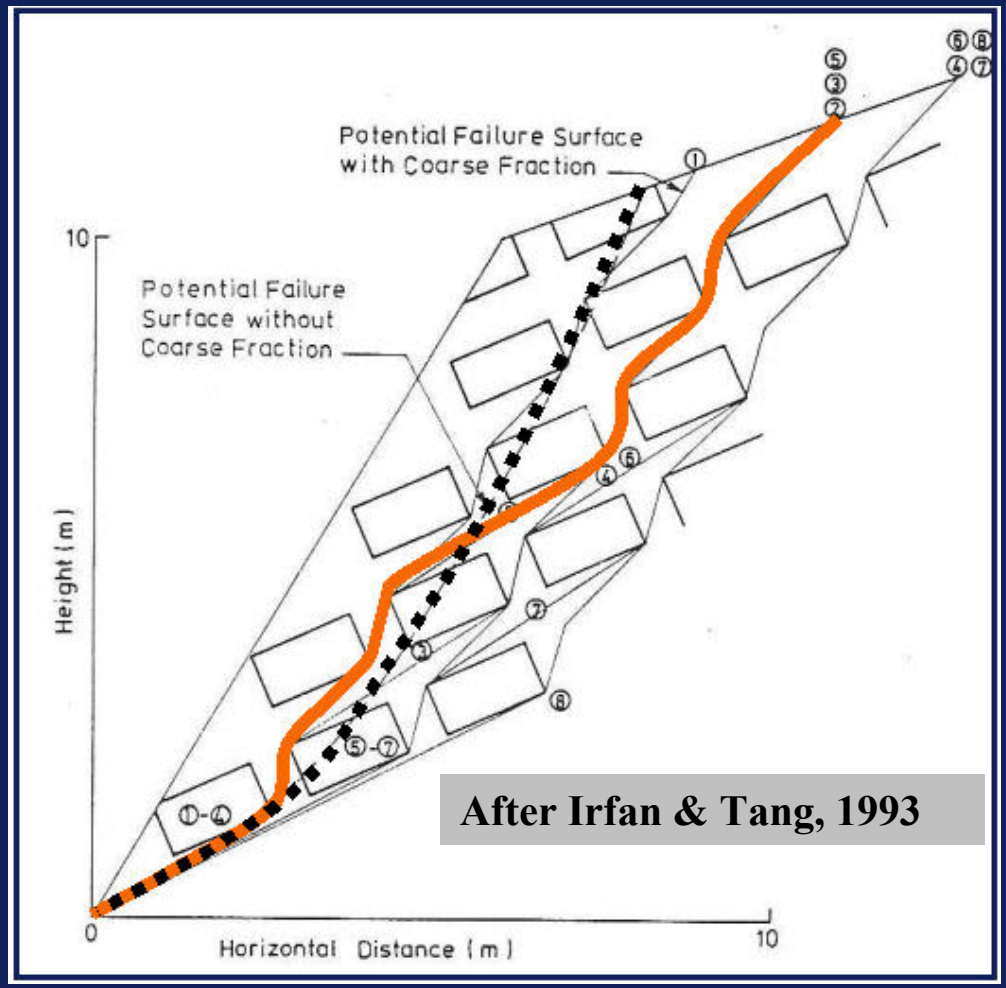


Negative No. SP89 030 08C Date : 17-4-89

Plate 29 - Colluvium Layer No. 1, Slope behind Fairmont Gardens

Hong Kong GEO TN 4/92

Trial tortuous failure surfaces with blocks oriented out-of-slope



After Irfan & Tang, 1993

Slip No	F.O.S.
1	1.05
2	1.15
3	1.09
4	1.18
5	1.08
6	1.15
7	1.16
8	1.19

Particle Dimension h x l (m x m)	Particle Spacing, ST/SL	Matrix Strength c' (kPa)	Matrix Strength φ' (deg)	Slope Height (m)
0.8 x 1.6	1.0	5	35	10

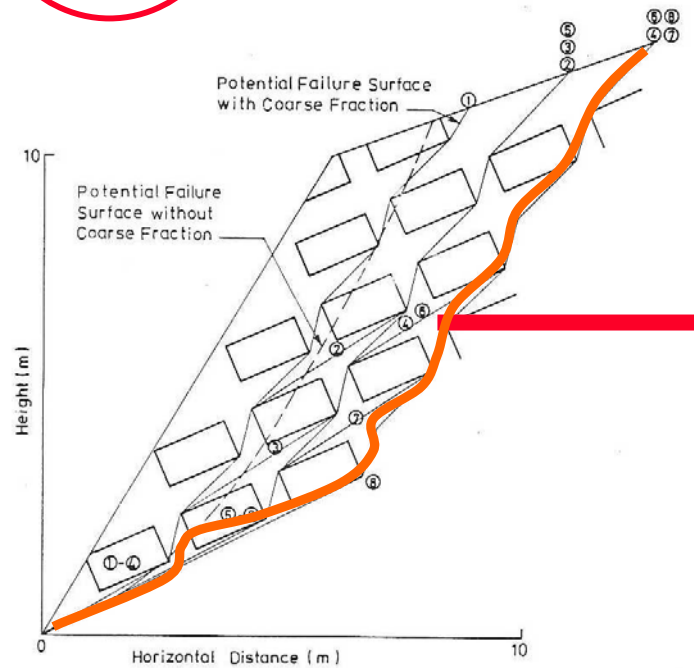


Figure 6.2 - Locations of Typical Potential Failure Surfaces in the Theoretical Slope Model

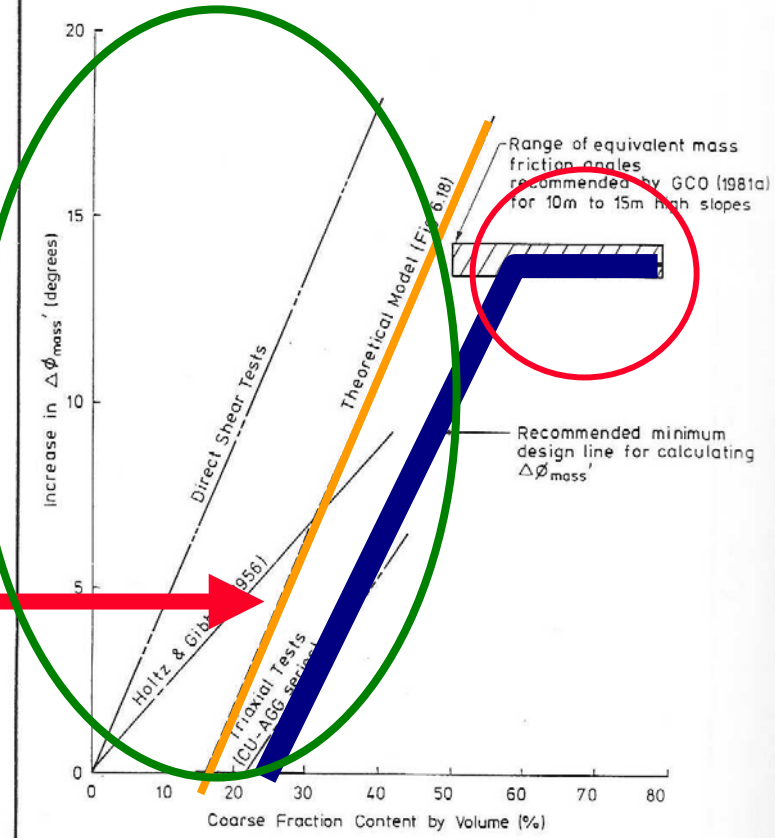
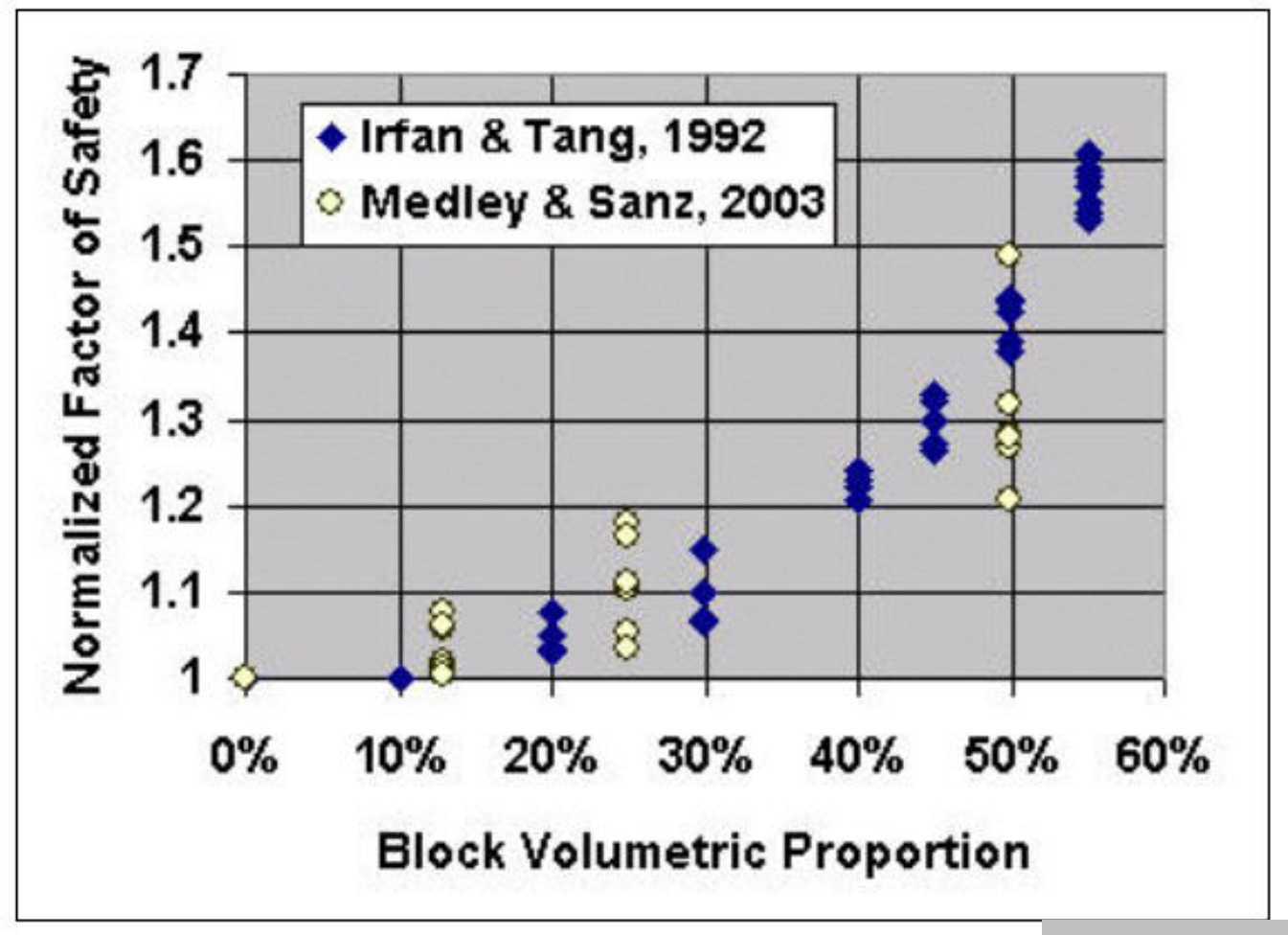


Figure 7.3 - Summary of the Hong Kong Study and the Recommendation for Mass Strength Increases For Slope Analysis in Colluvium

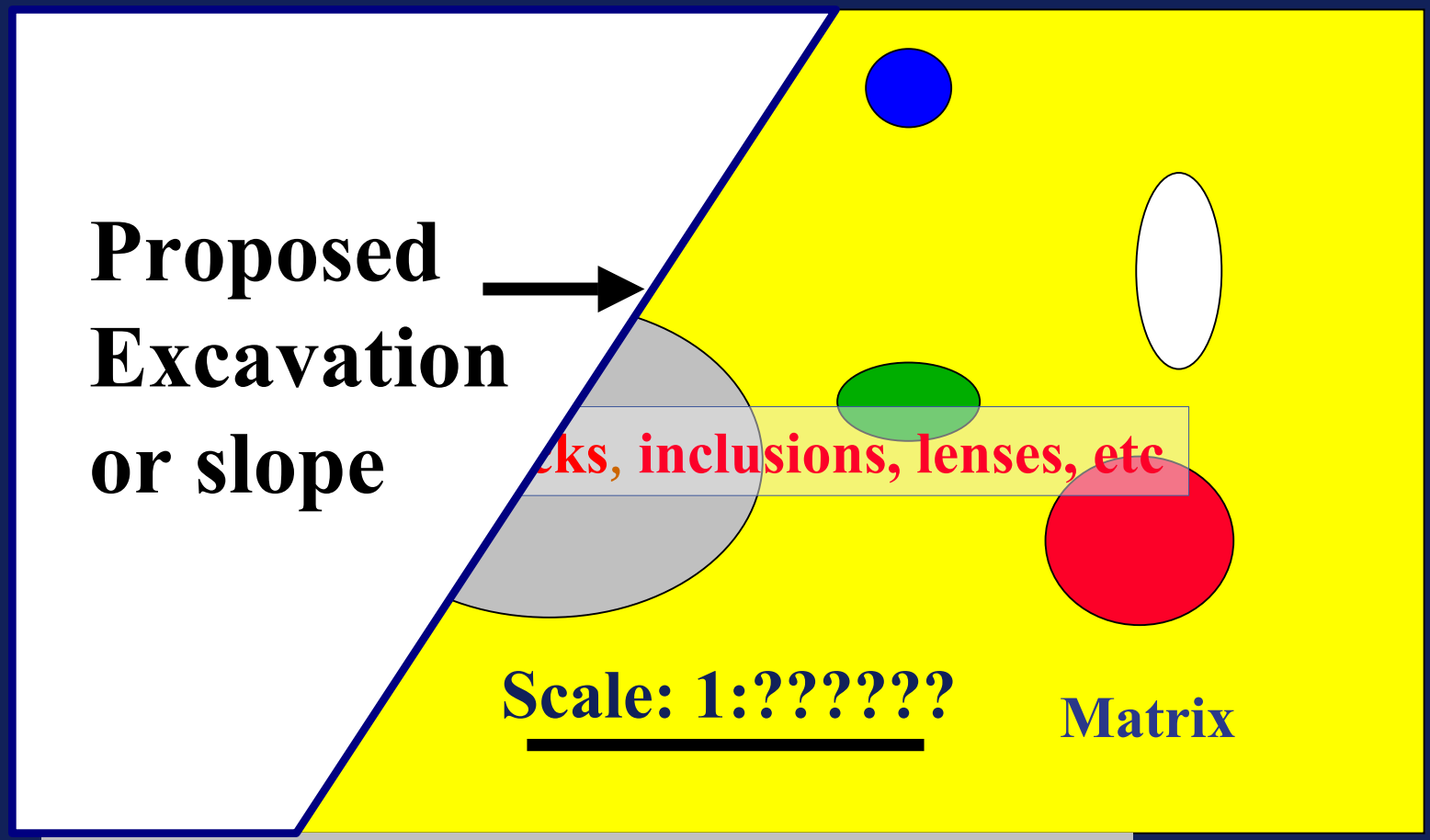
Irfan & Tang, 1993 GEO SPR 15/92

Combining the results of analyses: Block volumetric proportion is related to slope stability…



Medley & Sanz, in press

BIG CONCLUSION 1:
Remember this picture!!!



Actual Distribution of Blocks

Medley, 2000

BIG CONCLUSION 2:
Remember this picture as well!!!