SEMINAR 1

A Simple Lecture on Geological Complexity: How to Characterize Melange and Other Bimrocks

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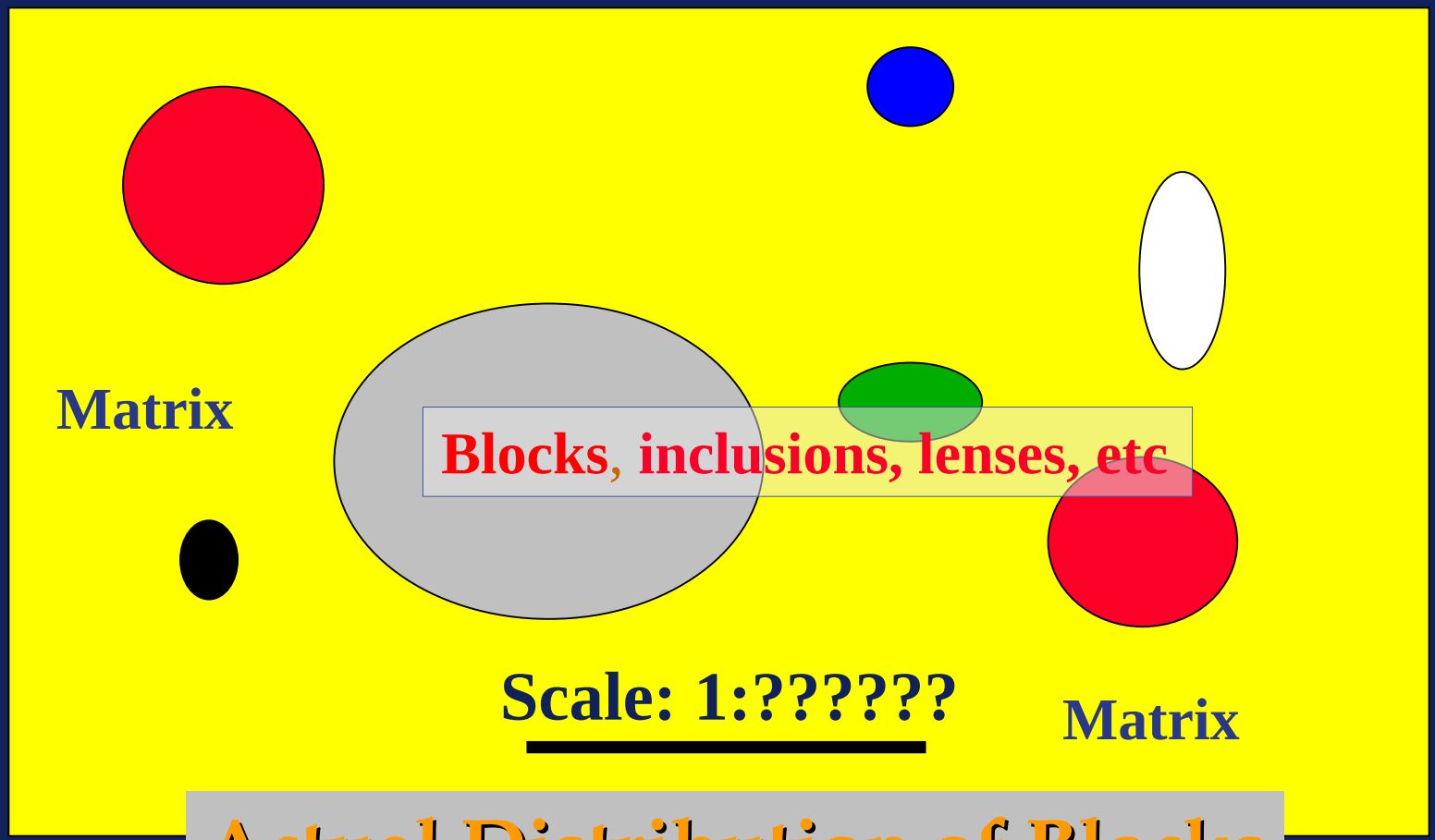
Bimrocks Short Course, Haceteppe Univ., Ankara

June 23, 2004

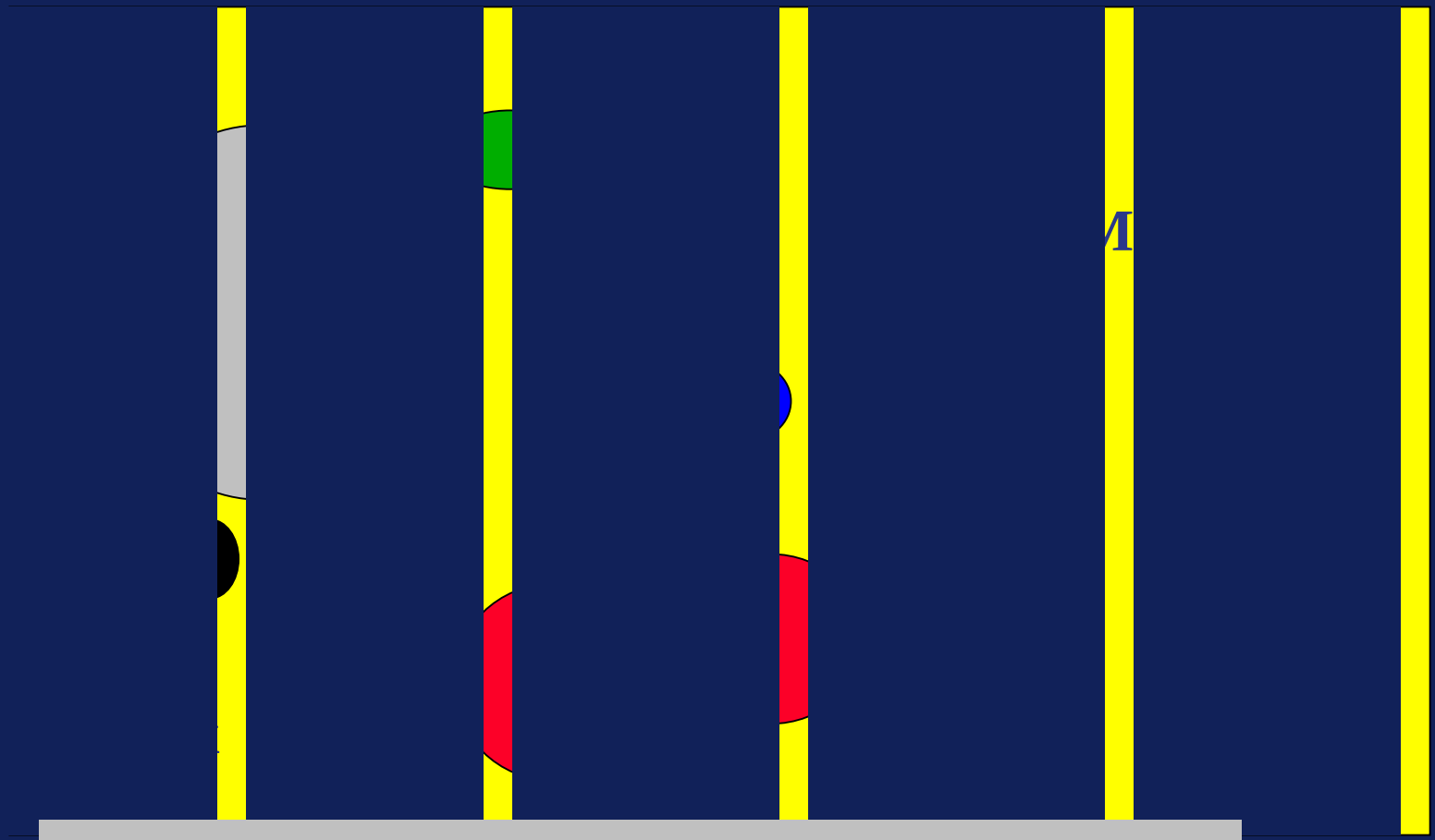
BIG CONCLUSION 1:
Remember this picture!!!



Actual Distribution of Blocks

Medley, 2000

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



Apparent Distribution of Blocks

Willis, 2000

Melanges and Similar Bimrocks

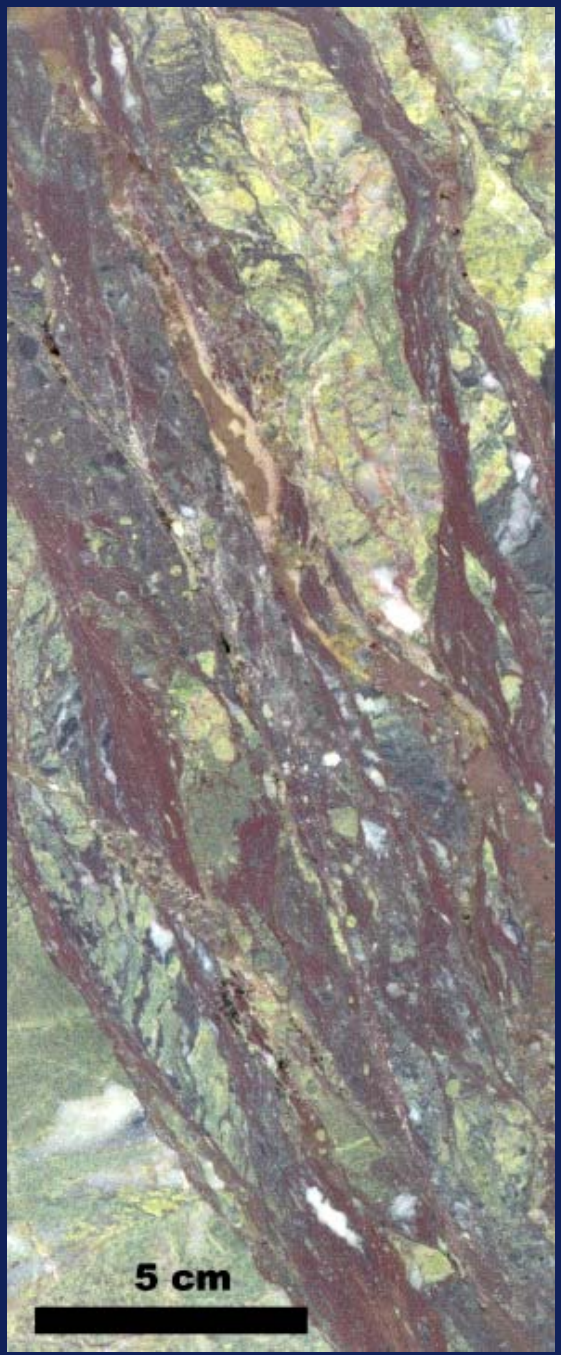
- **Melanges: (French *mélange*) :**

  UNCHILE mixtures of competent blocks composed of sedimentary/ metamorphic blocks in weaker matrix of sheared shale or serpentinite

- **Bimrocks: block-in-matrix rocks**
  - **mixtures of rocks composed of geotechnically significant blocks within a bonded matrix of finer texture**
- **Similar Bimrocks: Saprolites, Breccias, Fault Zones, Lahars, Tillites, etc.**

Example of weathered rock bimrock

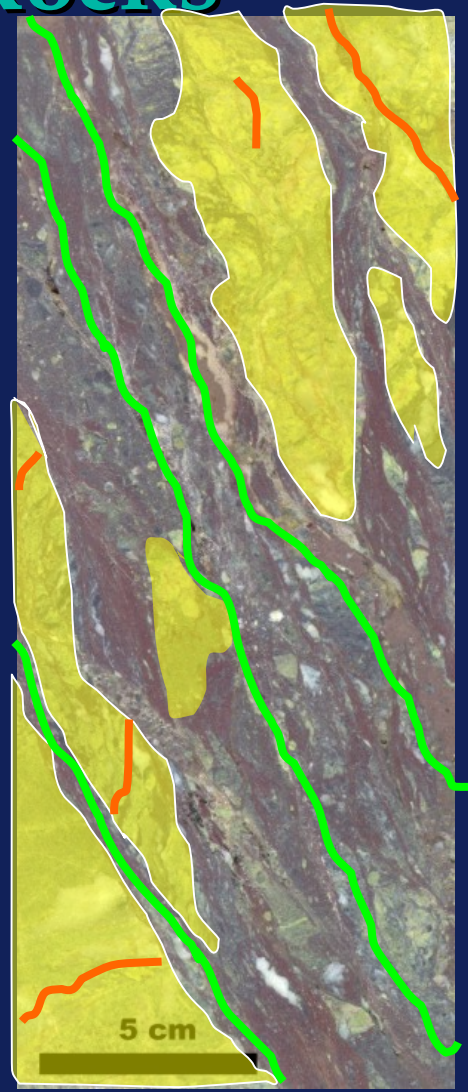
Mixture with weaker soil and strong blocks (decomposed granite at Hwy 50, California)



Fault Rocks and Shear Rocks

Fault zones and Shear zones may have blocks millimeters to 100s of meters wide:

BLOCK SIZE DISTRIBUTIONS TEND TO BE SCALE INDEPENDENT



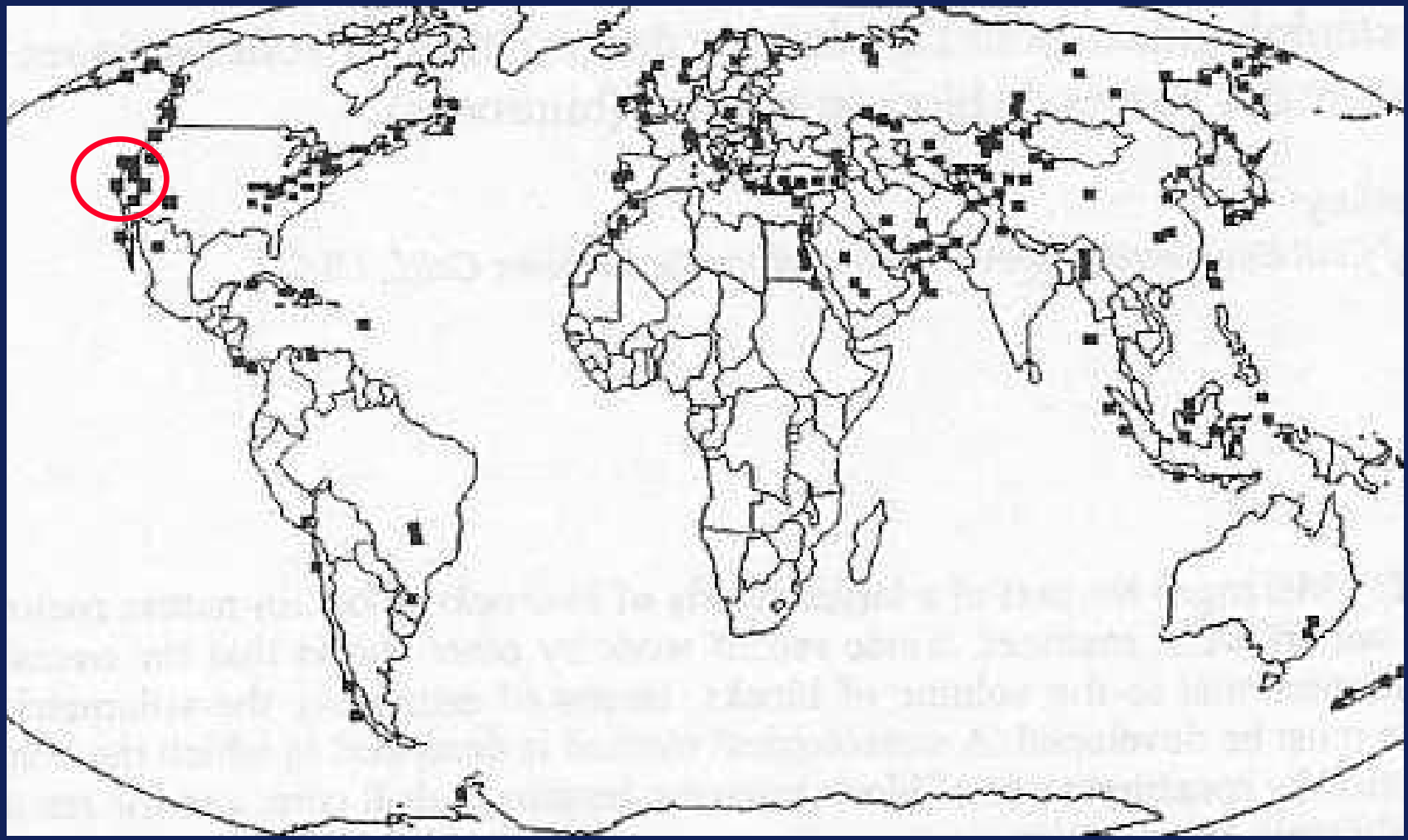
Riedmueller et al, 2001

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

Egnatia Motorway, Greece Photo by Prof. Gunter Riedmueller

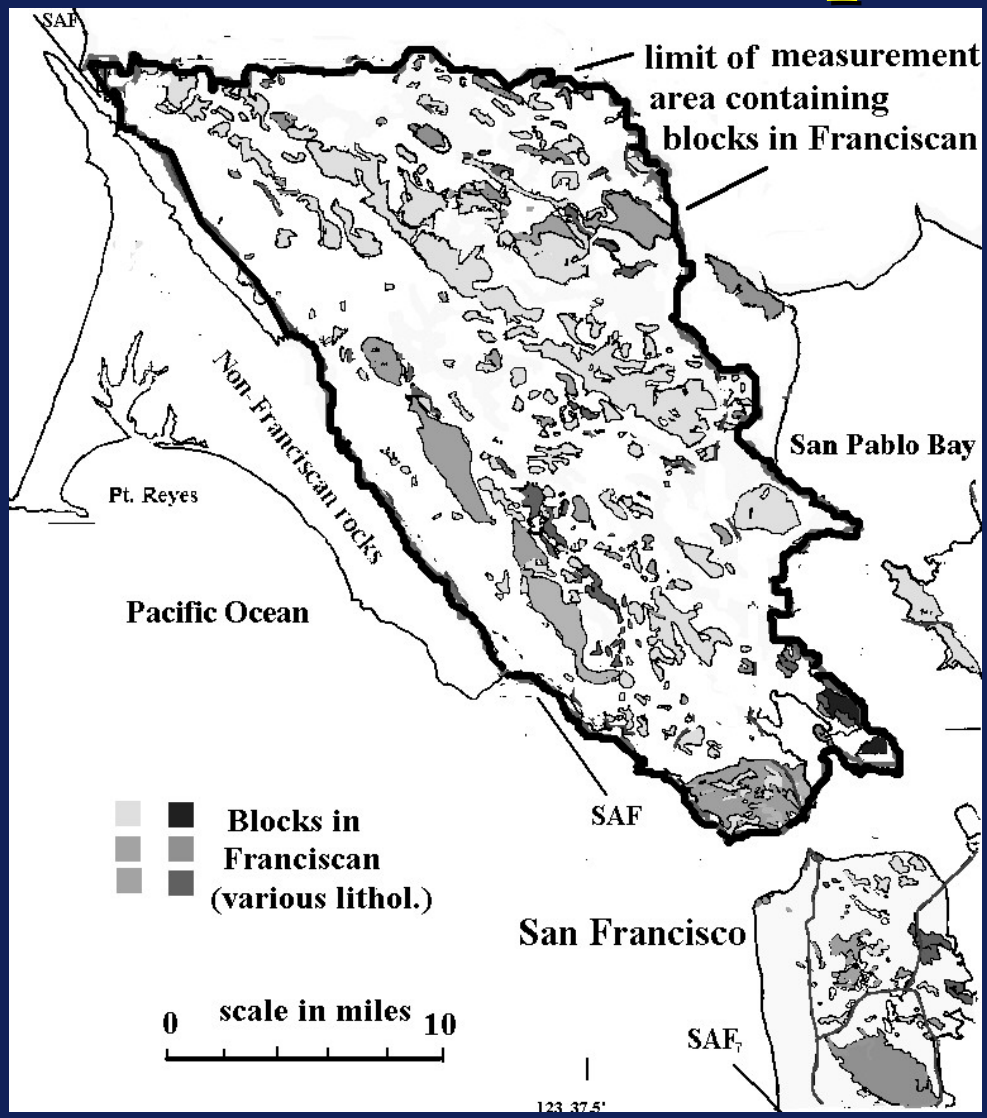
Gruppe Geotechnik Graz ZT GMBH

Global distribution of melanges



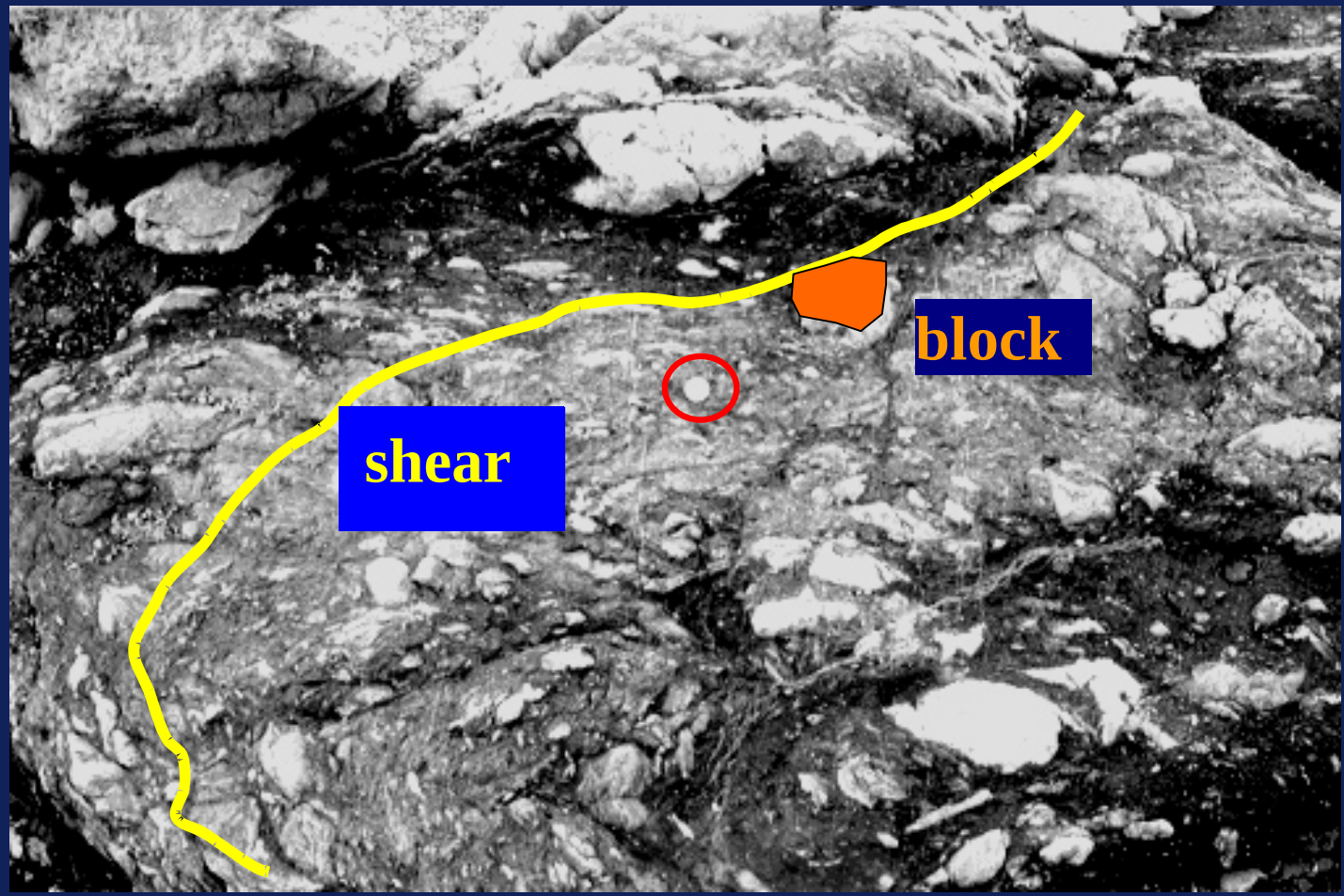
Medley, 1994

Franciscan Complex melanges



From Medley, 1994; after Ellen and Wentworth, 1995

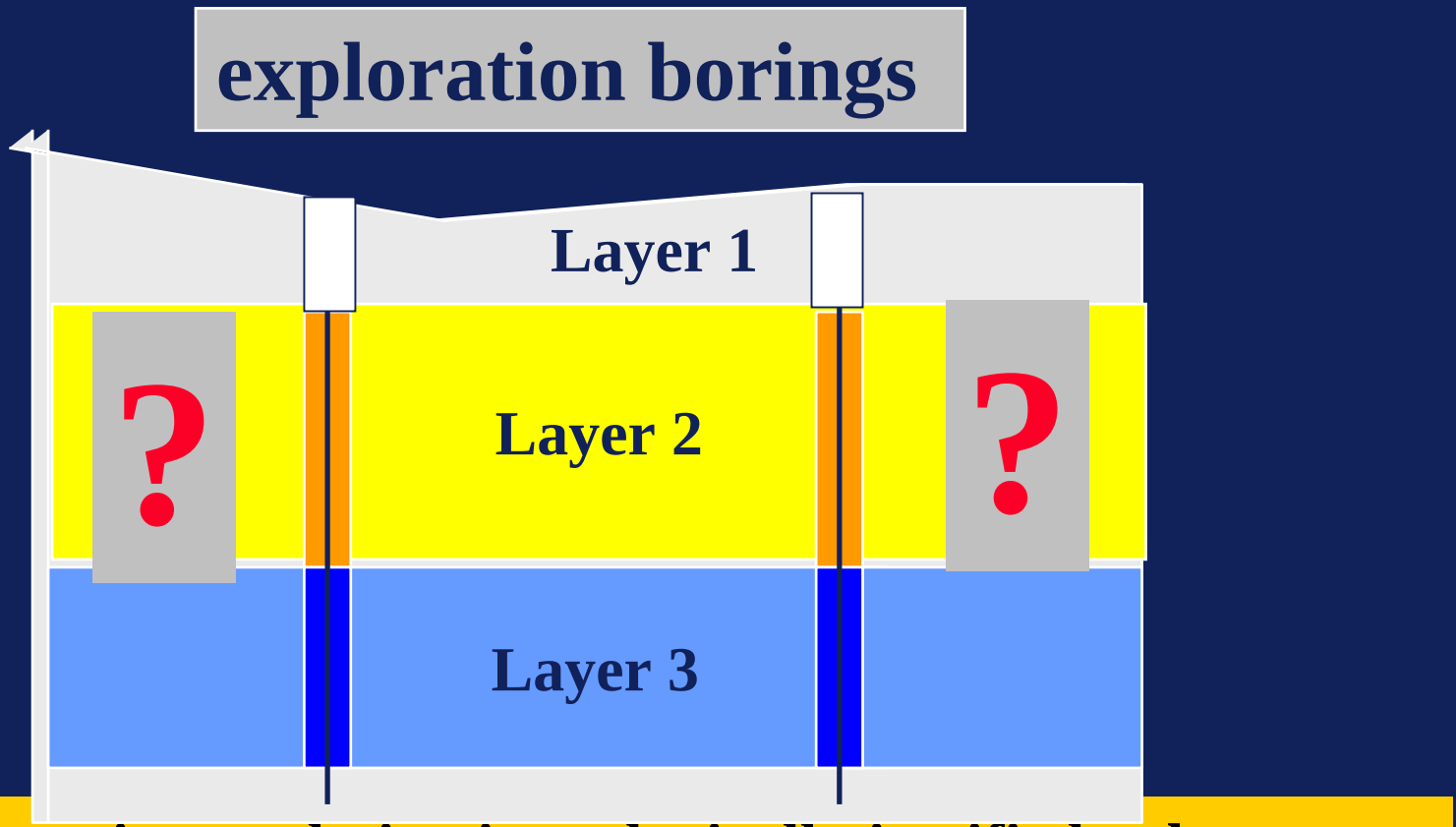
Franciscan Complex melange (Point Delgada, California)



$$Problems with Melanges

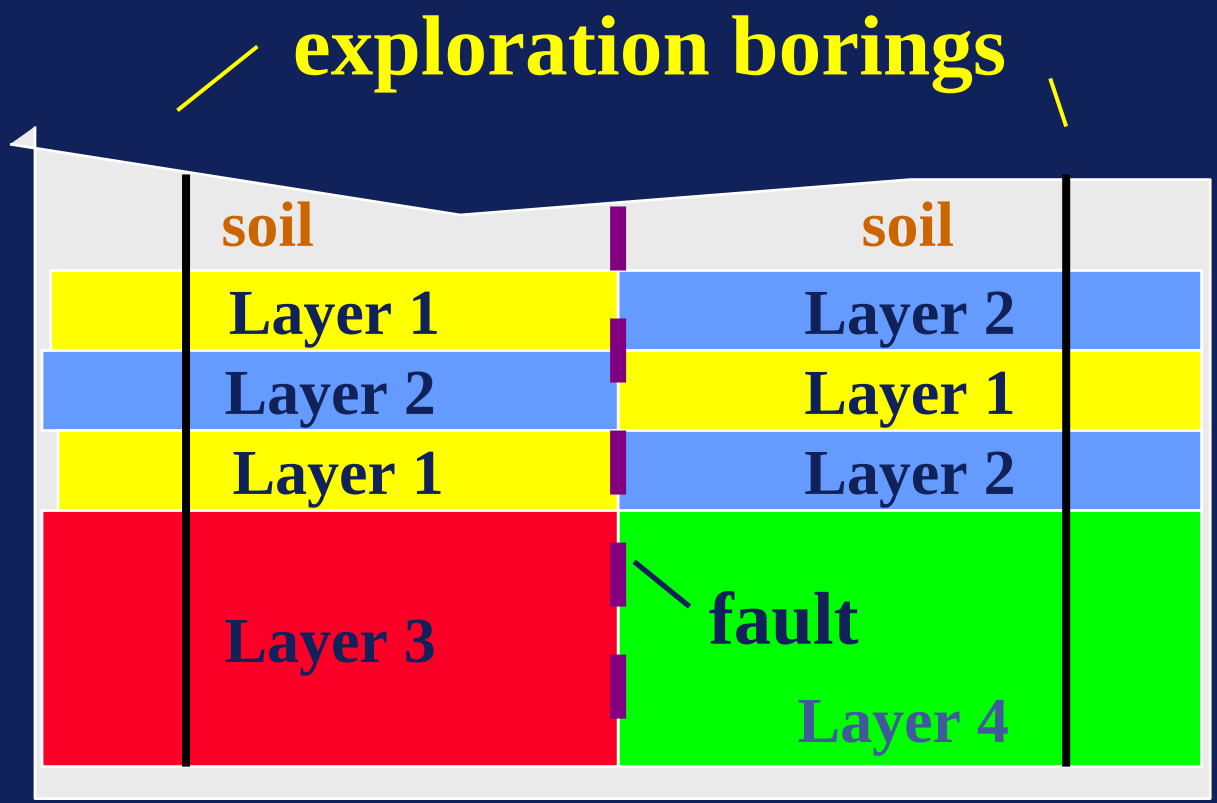
- Often severe spatial variability
- Heterogeneity in properties
- Design and construction shortcomings in characterizations cost someone $$$$, (usually the Owner and/or Contractor)

Geology 101 Subsurface characterization of layer cake geology



Linear interpolation is geologically justified only SOMETIMES; extrapolation RARELY

Difficult geology:
lots of layers (“complex formations”)



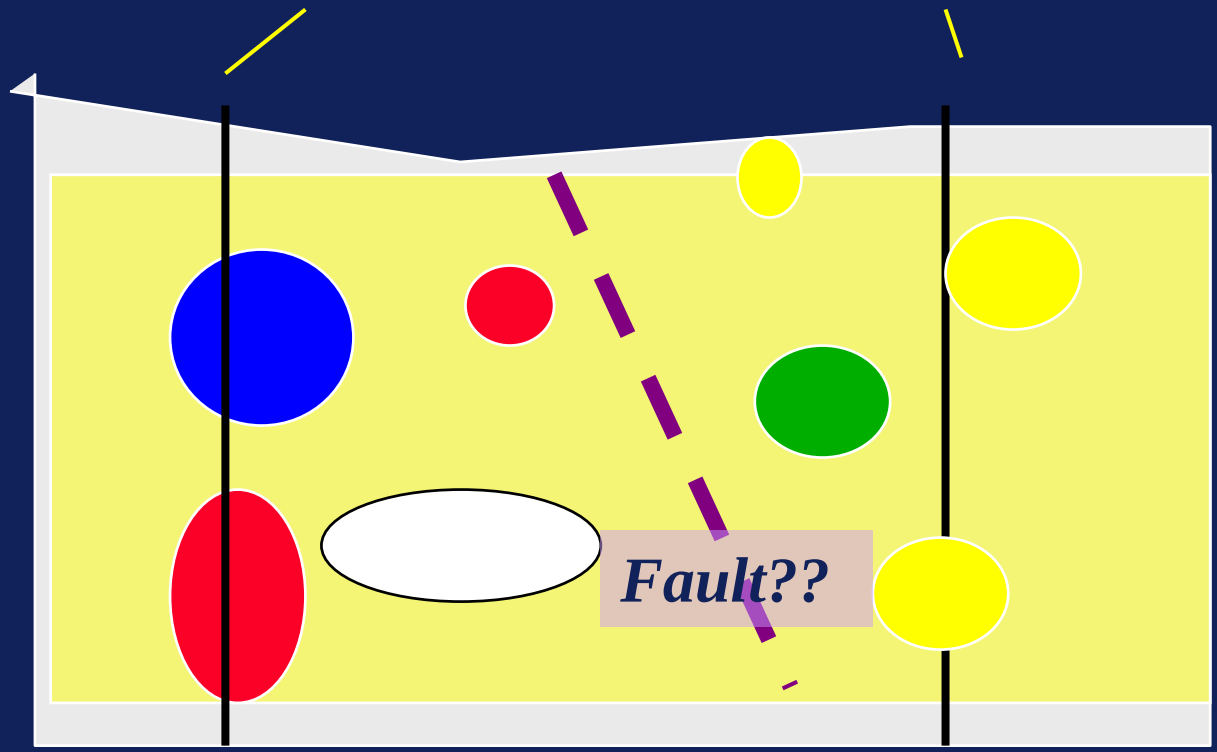
The complexity of a turbidite sequence - interbedded sandstones and shales

(Devil's Slide, Pacifica, California)

Chaotic Geology:

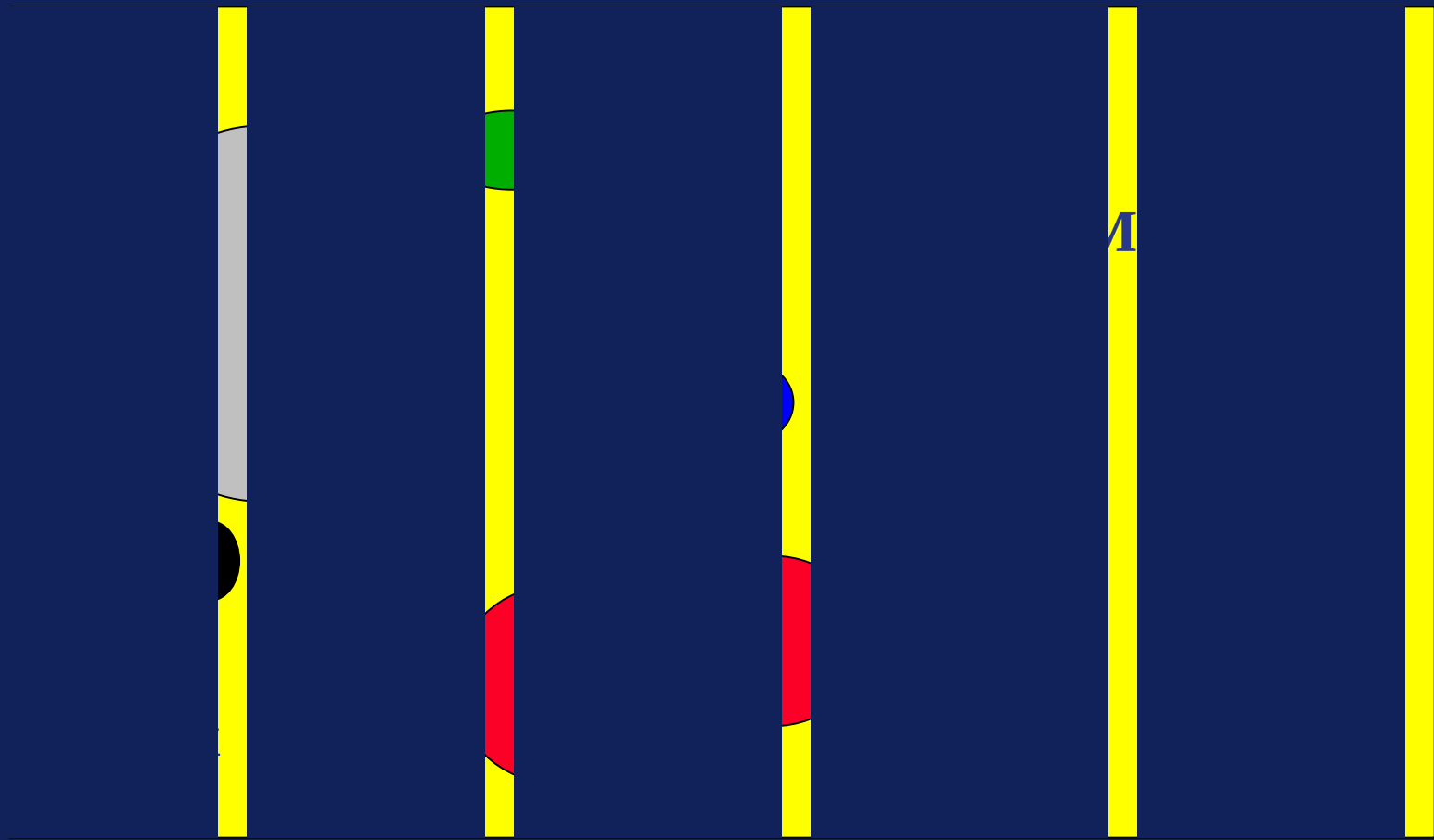
apparent "layers" are blocks, lenses, inclusions…..

exploration borings



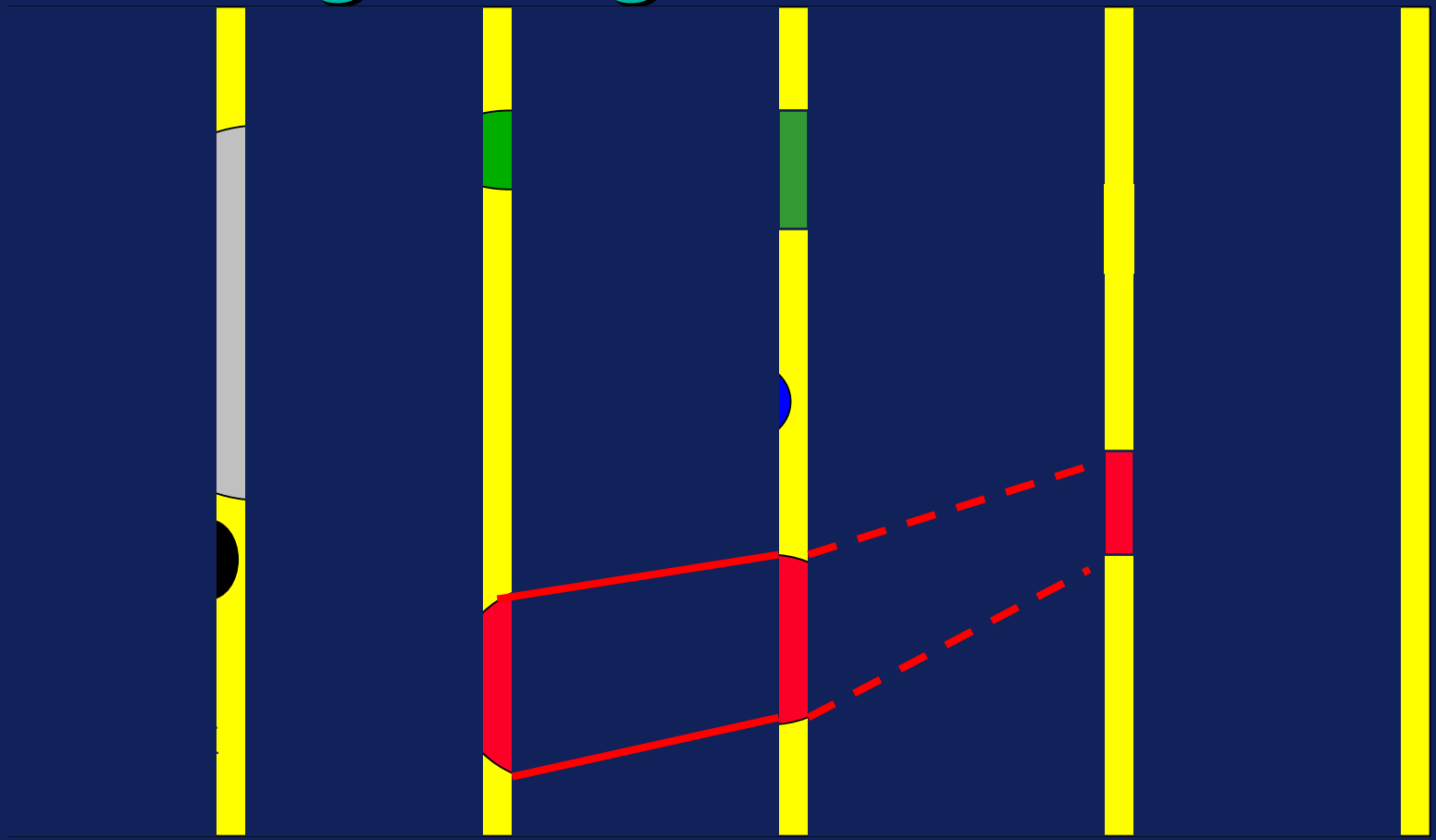
Characterization is NOT a piece of cake!

Bimrock – Mapped or cored

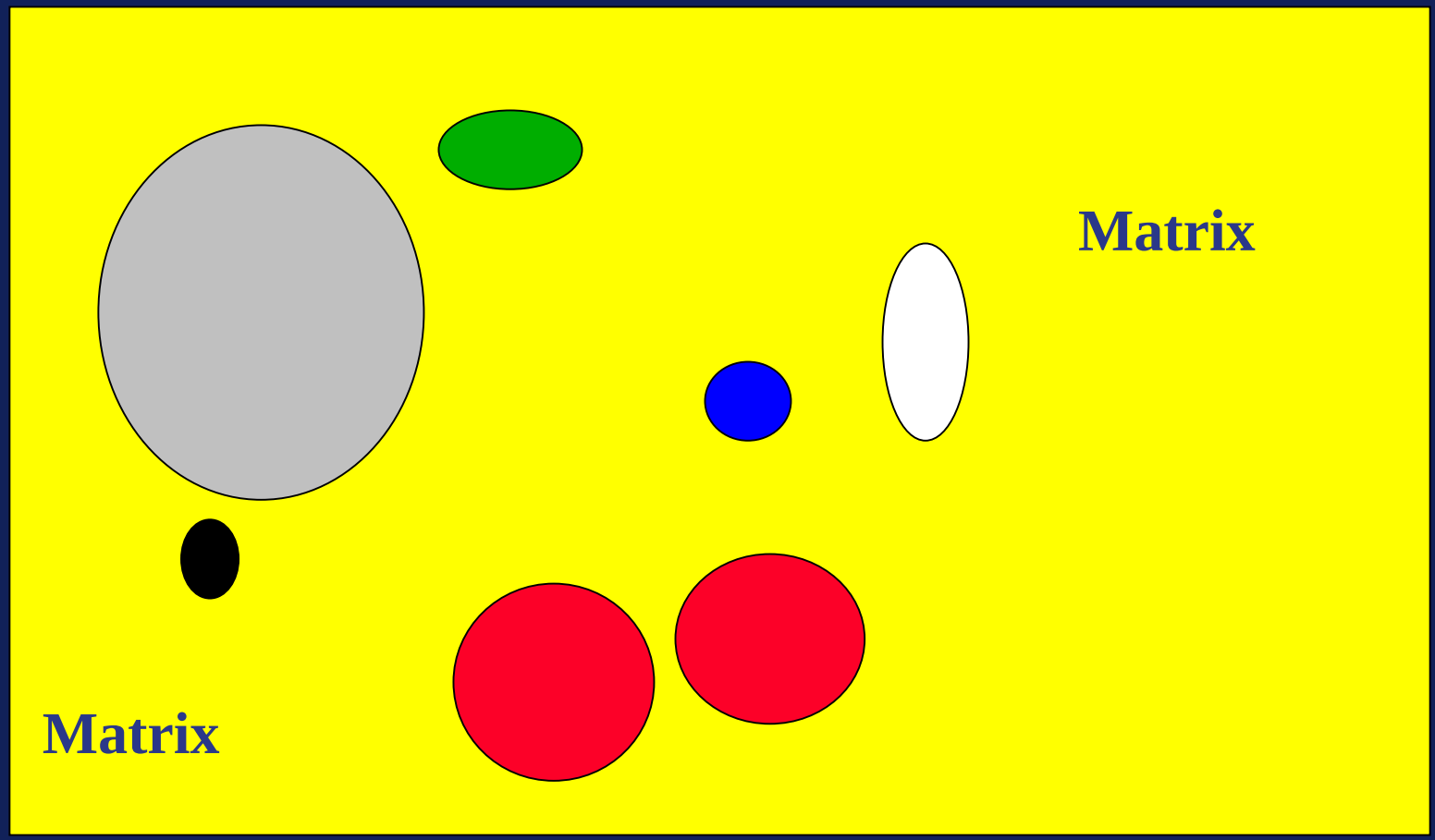


Willis, 2000

The Benefits and Dangers of Drawing Straight Lines



Actual Distribution of Blocks



Willis, 2000; after Medley, 2000

So What? Who Cares*?

*Answer: Owners, Contractors and Lawyers

Characterization of Melanges and Similar Bimrocks

Steps in Characterization of Bimrocks

- 1. Determine you are working in a bimrock
- 2. Select the Characteristic Engineering Dimensions of interest
- 3. Perform field mapping of geological and geotechnical features
- 4. Drill using careful drillers!
- 5. Measure areal and linear block proportions

More Steps in Characterization of Bimrocks

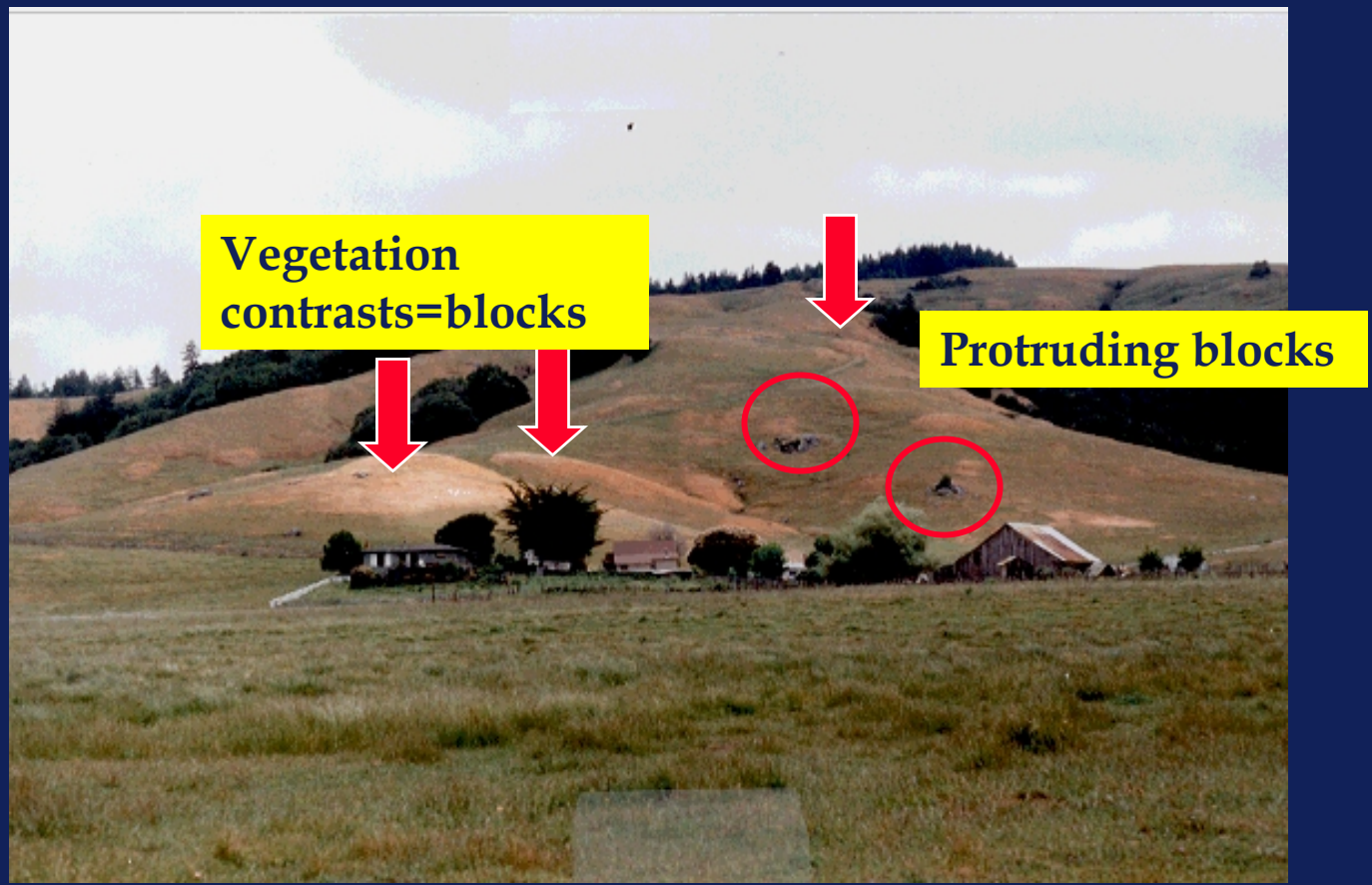
- 6. Select specimens for laboratory testing with blocks
- 7. Test a variety of specimens with different block proportions
- 8. Adjust your linear block proportion to account for uncertainty
- 9. Estimate overall bimrock strength

1. Determine you are working in a bimrock

Really obvious melange….

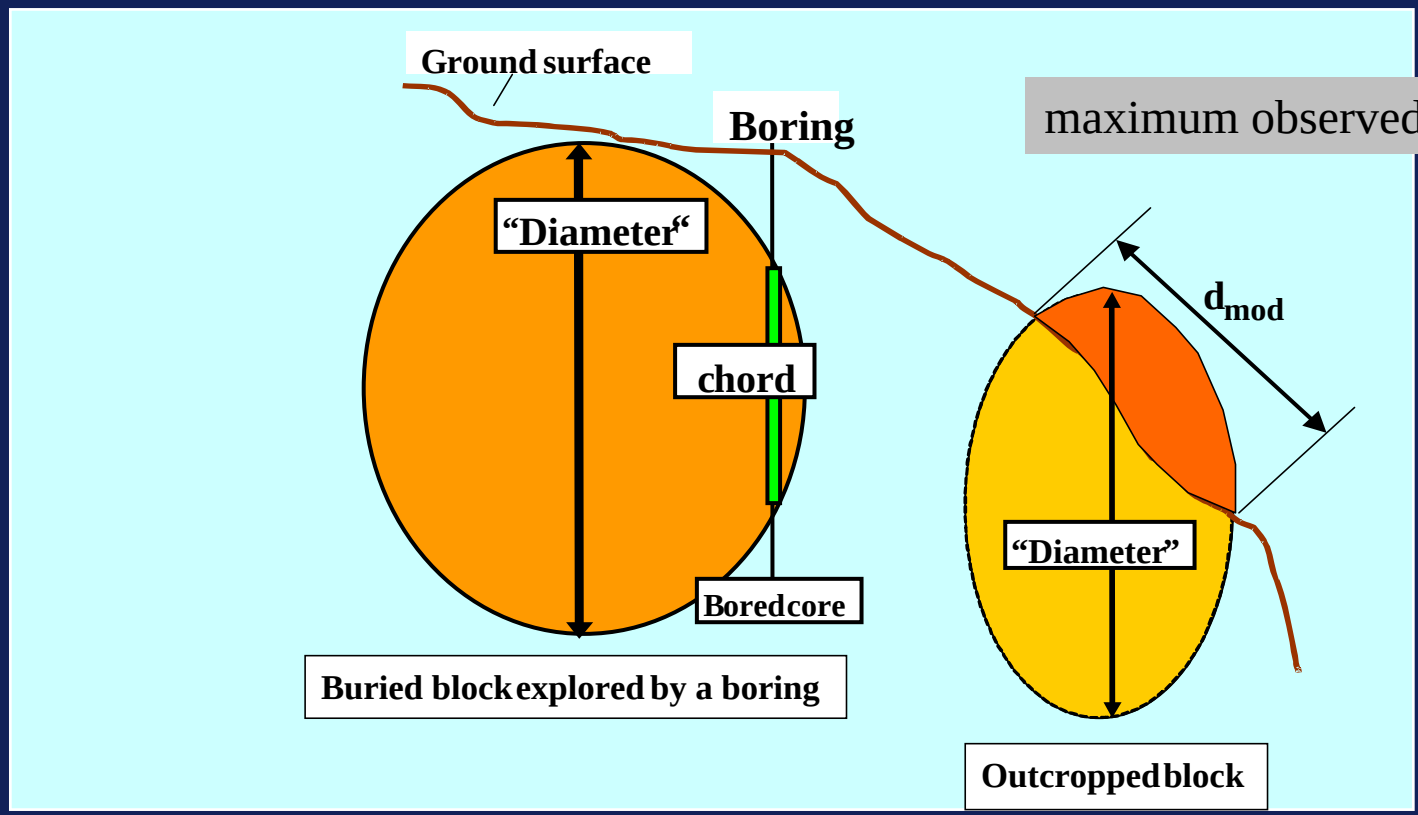
Gwna Melange, N. Wales photo Ed Medley

Geomorphic clues: subtle!!



2. Select the Characteristic Engineering Dimensions of interest

Q: What is Block Size??



A: Rarely the "diameter"

Blocks in Franciscan Melange

- Blocks range in size between mountains and sand and will always be found
- Block size distributions are scale independent and fractal (power law)
- Largest reasonable block is:

$$0.75\sqrt{A} \quad \text{aka} \quad d_{max}$$

- Block/matrix threshold is $0.05\sqrt{A}$
- Characterization must take blocks into account

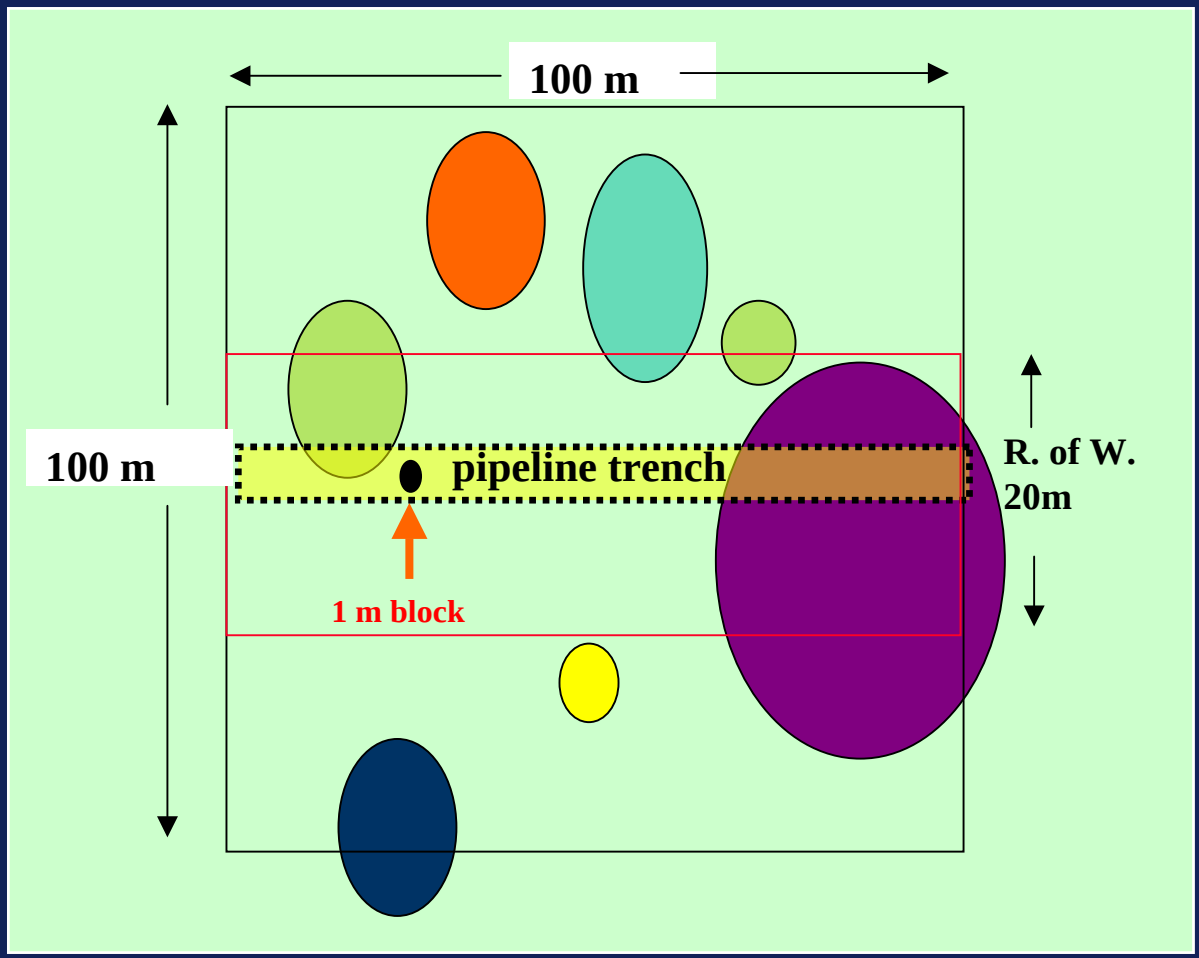
Use these guidelines at *any scale of interest*

- **smallest blocks are:**

  $0.05L_c$ **or** $0.05\sqrt{A}$ **or** $0.05d_{max}$

- **largest block is:**

  $0.75L_c$ **or** $0.75\sqrt{A}$ **or** $0.75d_{max}$



When is a block not a block?

depends on scale of interest

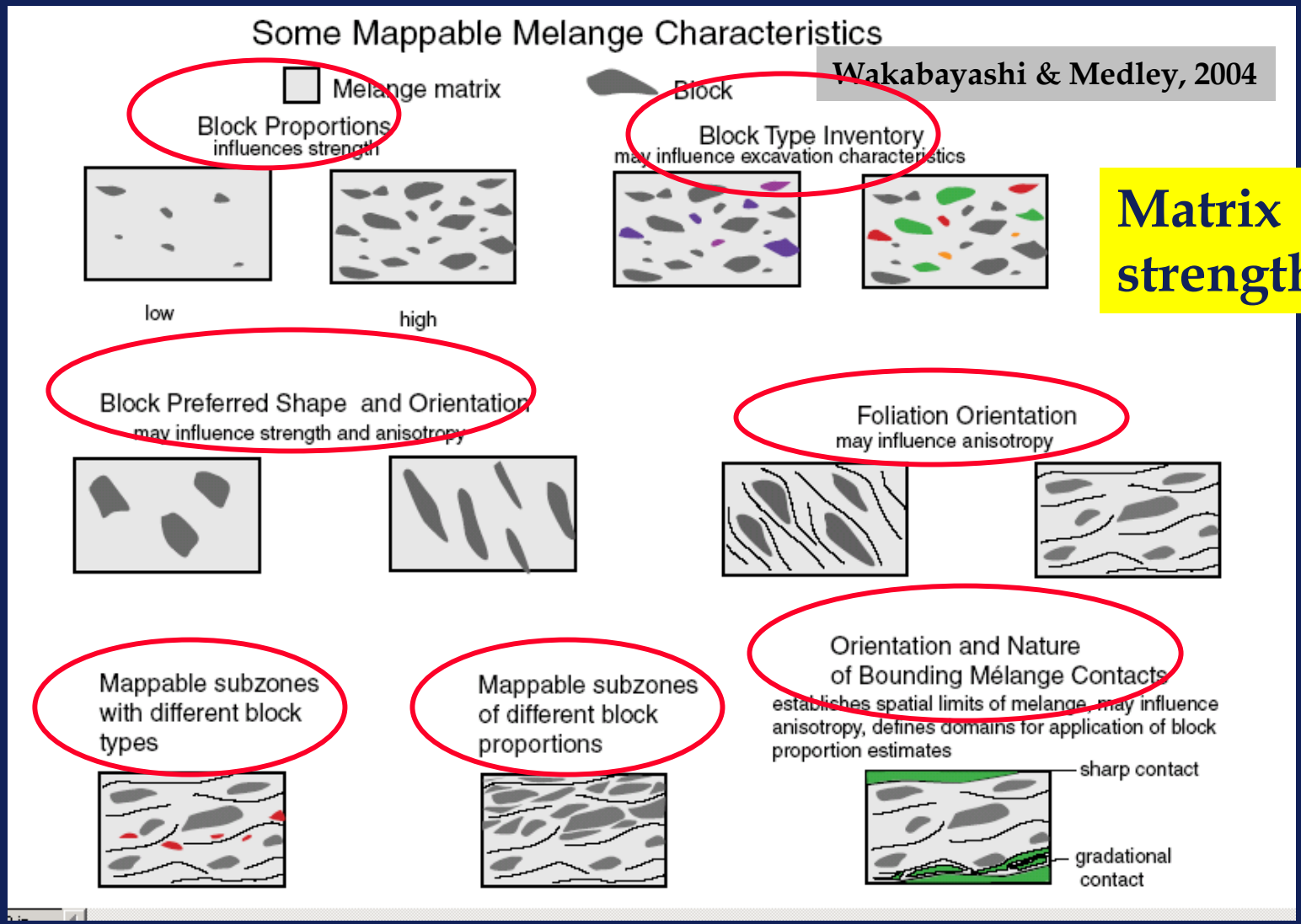
3. Perform field mapping of geological and geotechnical features

Some elements of CHARACTERIZATION

- Block/matrix discrimination Matrix lithology,
- block lithology, block size, block shape,
- block orientation
- Block size distribution
- Block discontinuities
- Etc…

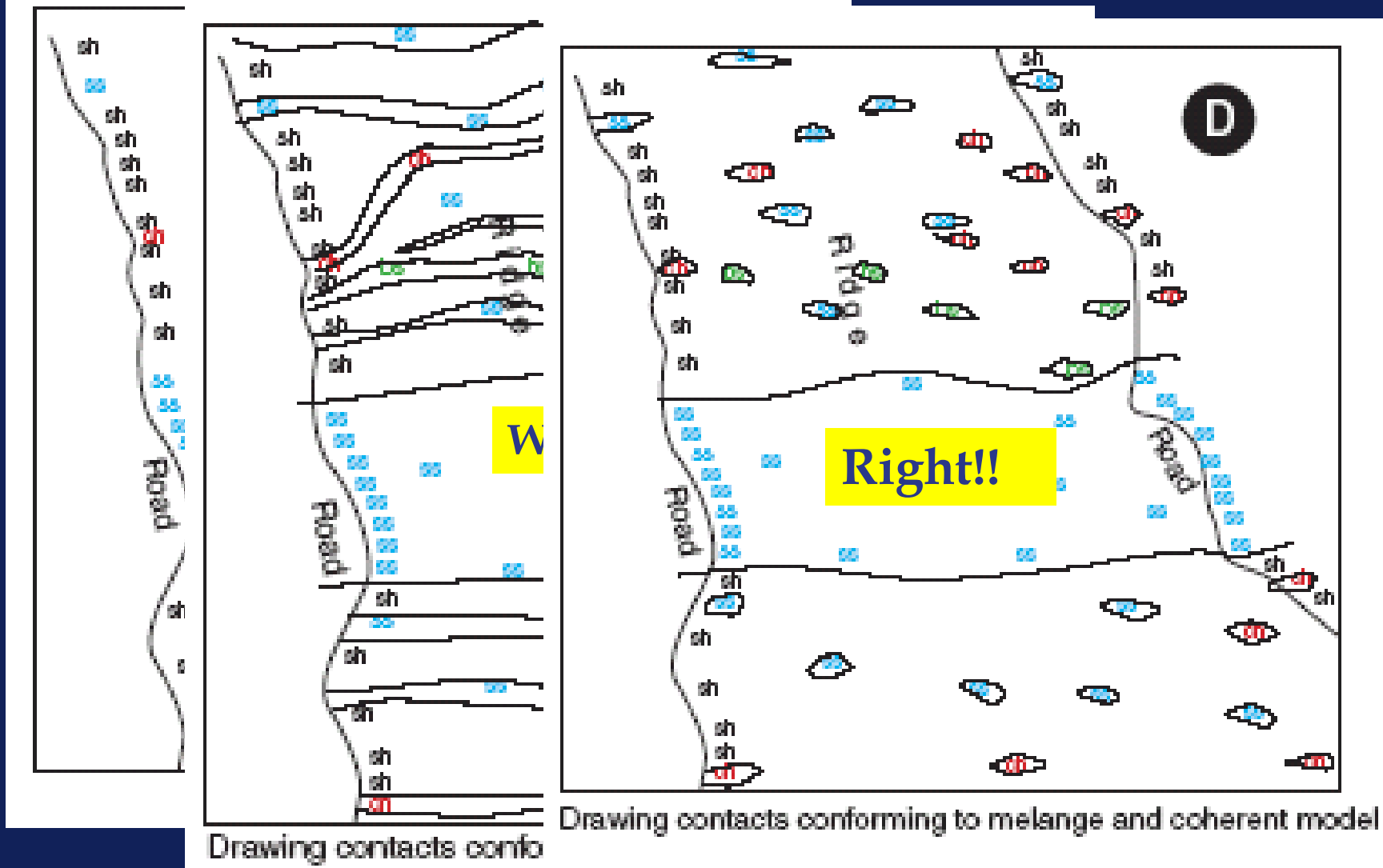
ALL are straight forward geological engineering during field investigation…

Systematic investigation of chaos



Matrix strength

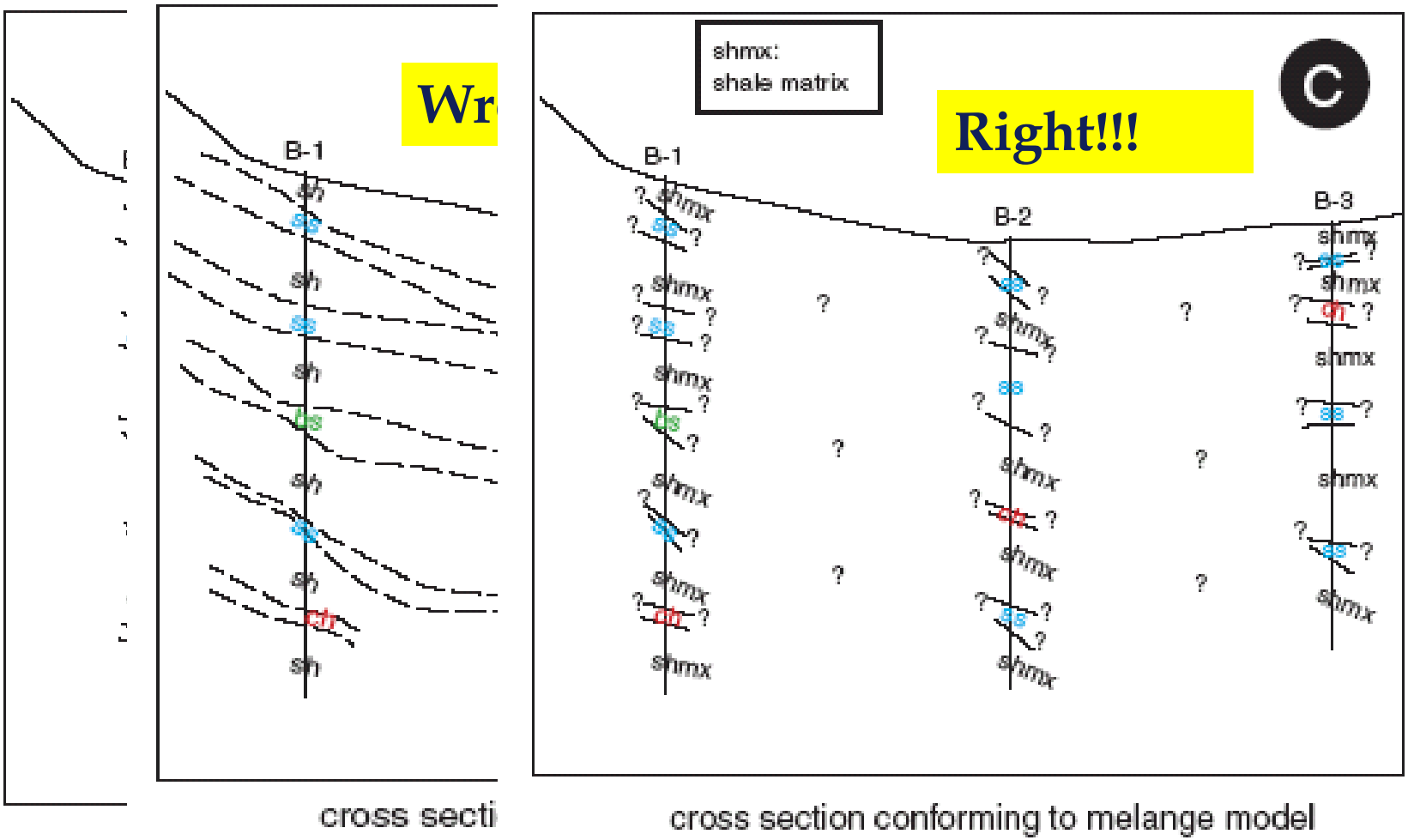
Right and wrong way to map melanges



Observe block/matrix contacts

4. Drill using careful drillers!

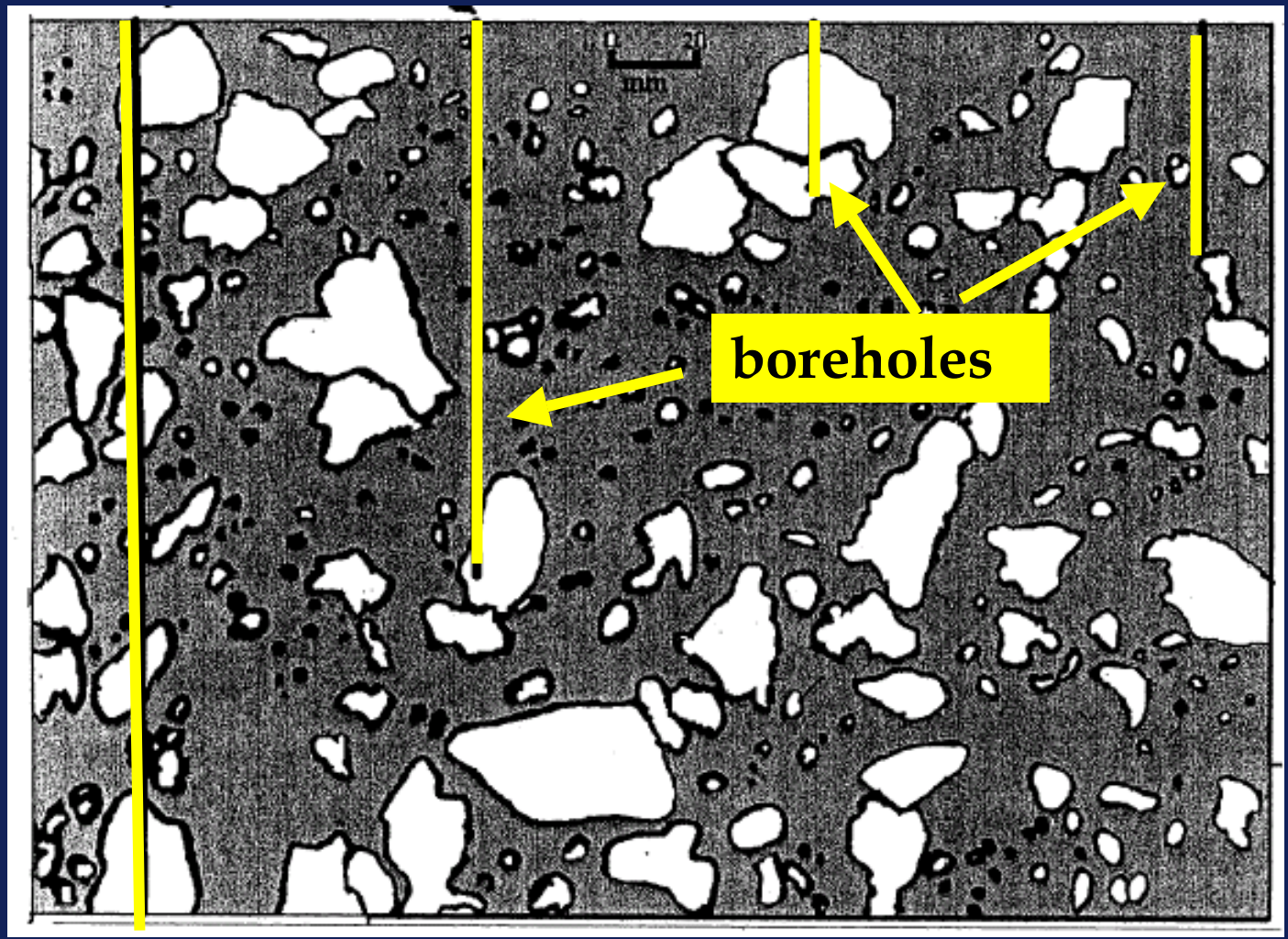
right way and the wrong way…



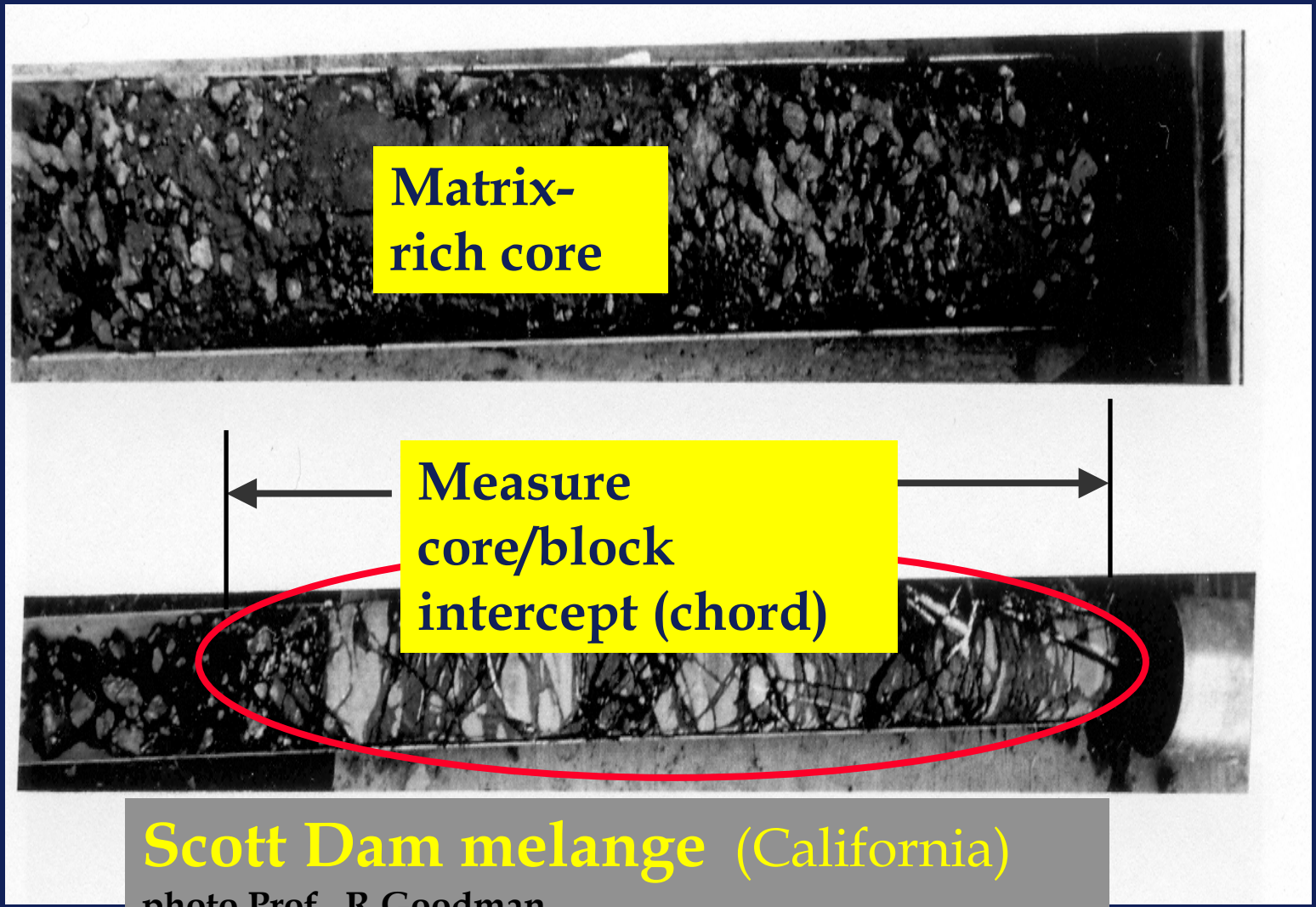
Wakabayashi & Medley, 2004

5. Measure areal and linear block proportions

Drilling and coring bimrocks

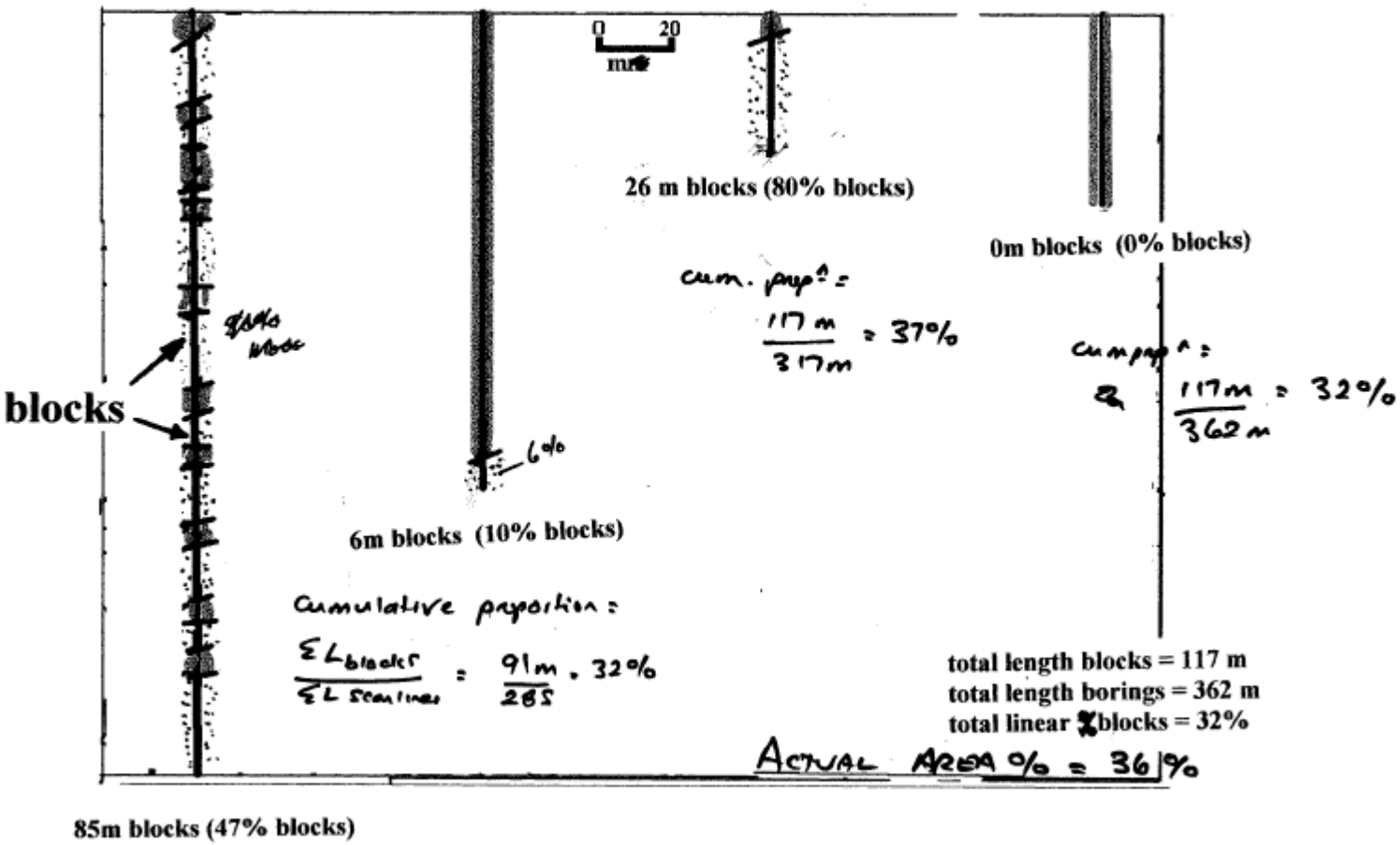


Measure block linear proportion



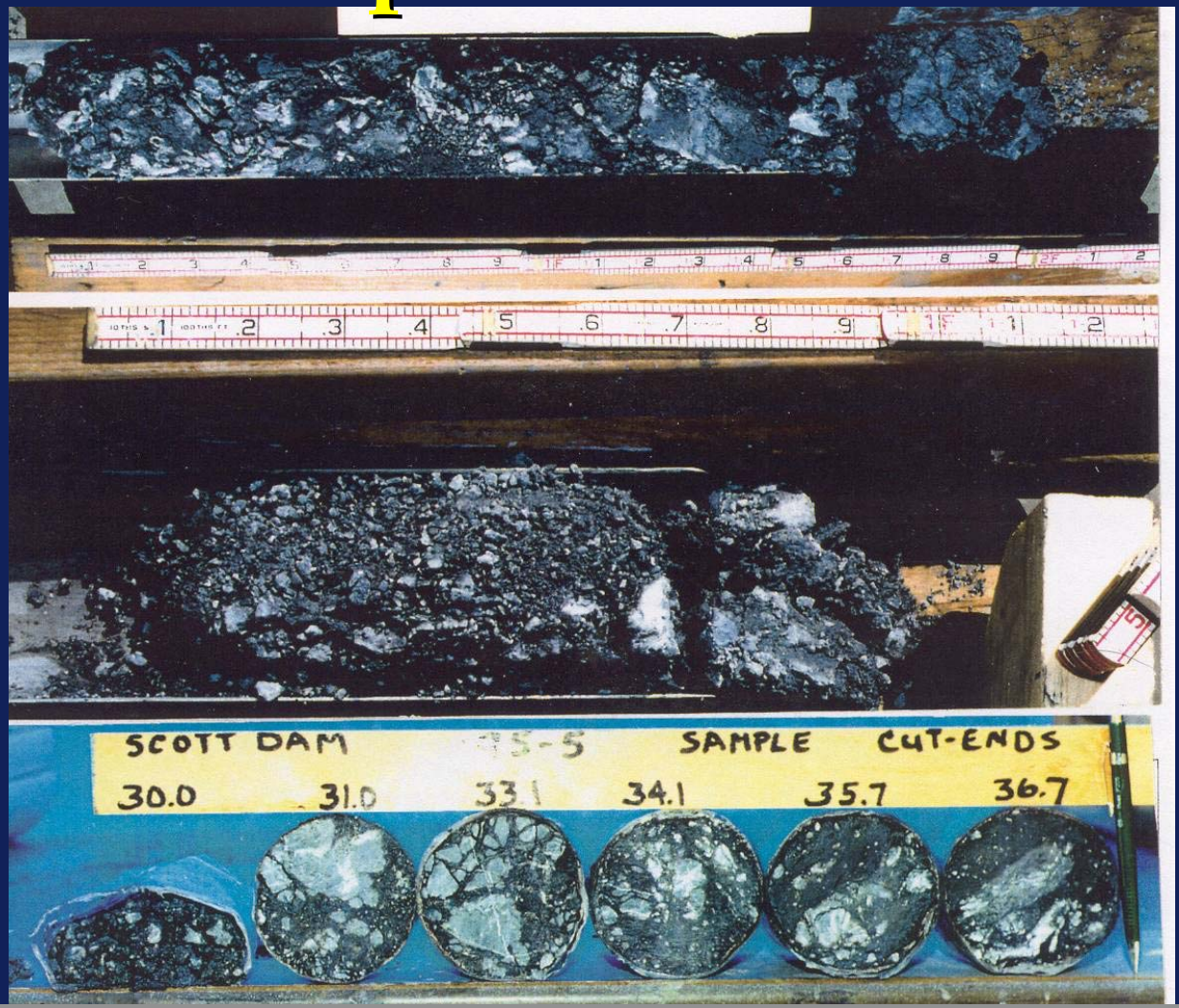
Scott Dam melange (California)
photo Prof . R Goodman

Measuring Linear Proportion



6. Select specimens for laboratory testing with blocks

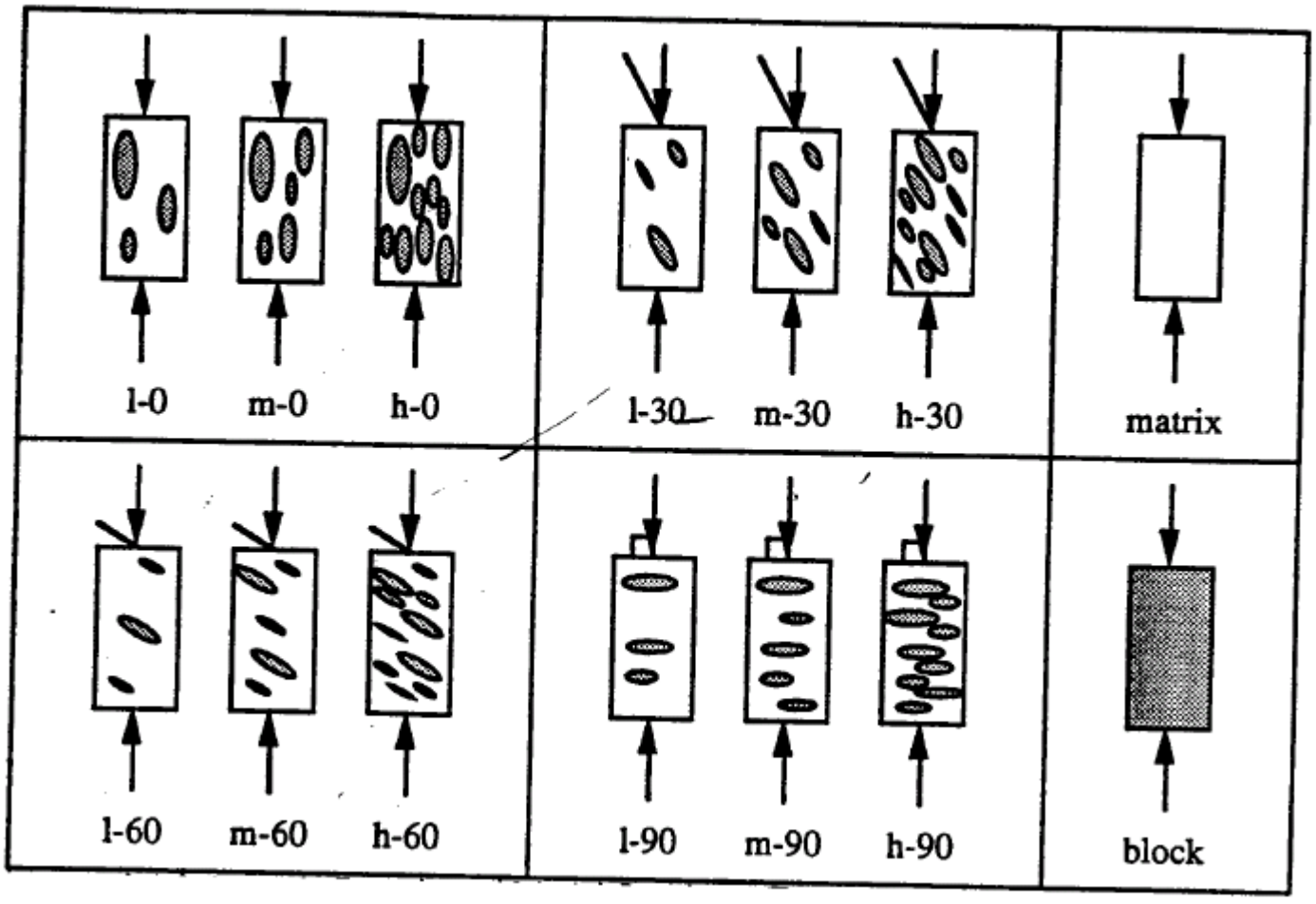
Take samples of matrix



Scott Dam melange photo Prof. R Goodman

7. Test a variety of specimens with different block proportions

Different orientations and volumetric block proportions



Lindquist, 1994

Increase in friction angle with volumetric block proportion

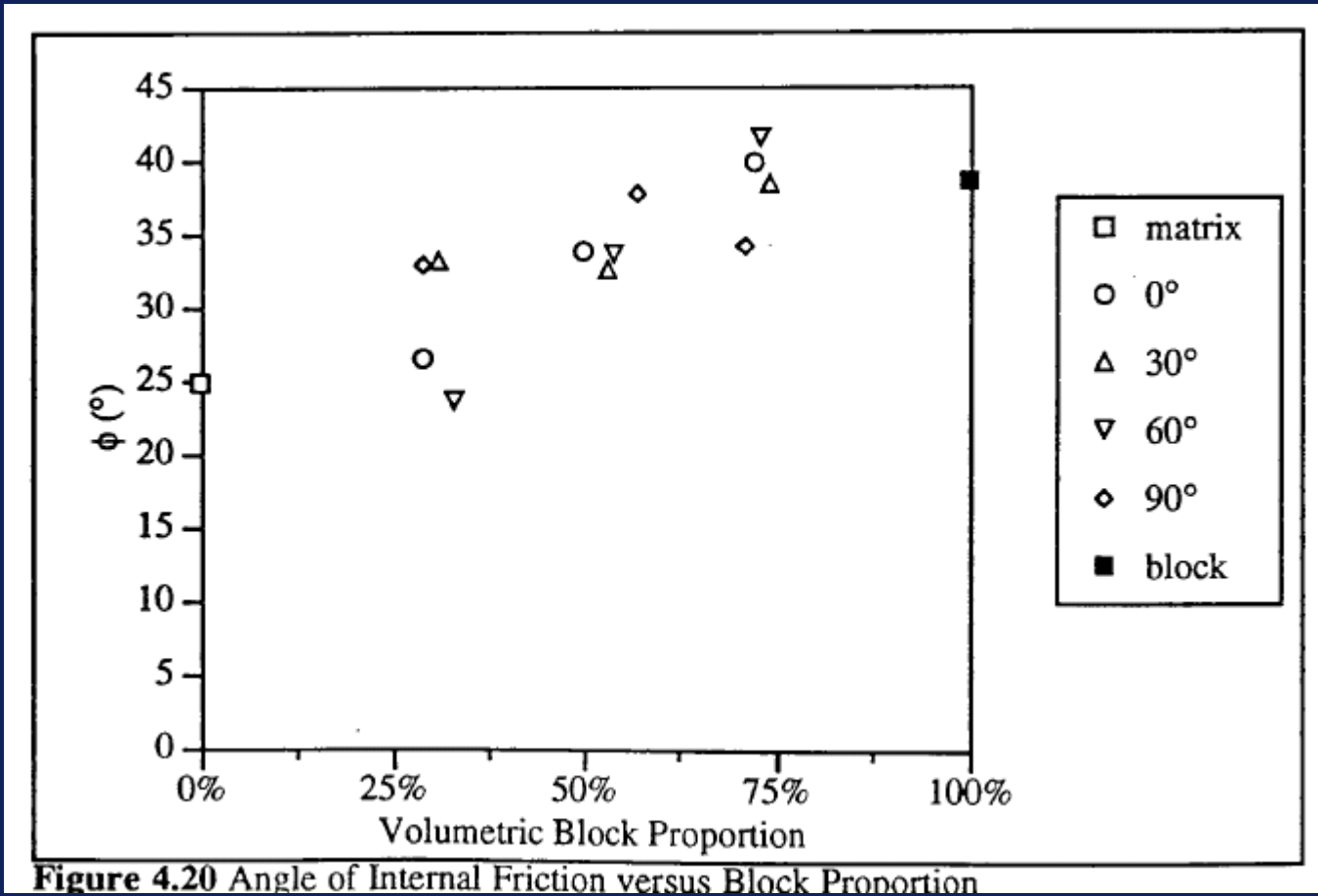


Figure 4.20 Angle of Internal Friction versus Block Proportion

Lindquist, 1994

Decrease in cohesion with volumetric block proportion

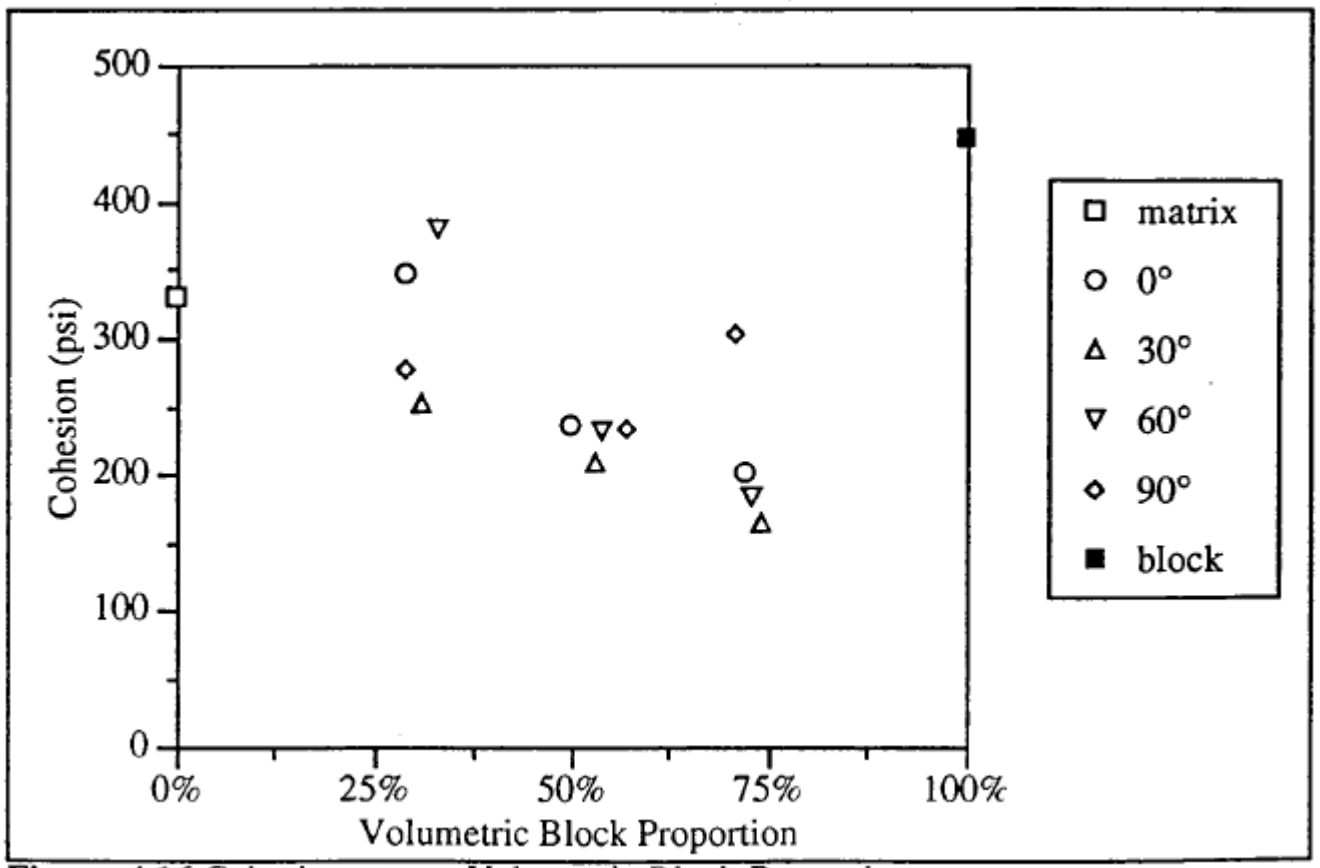
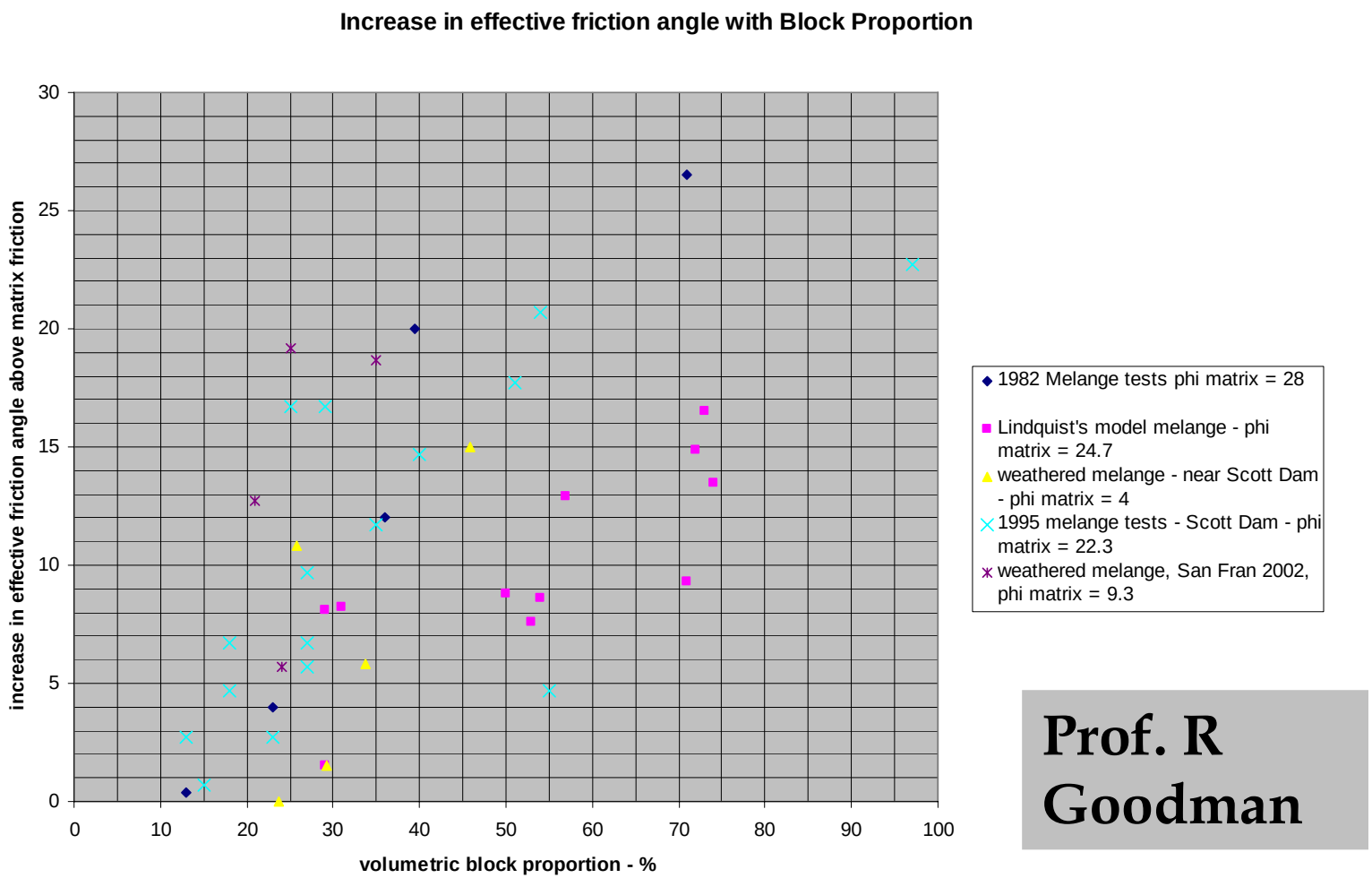


Figure 4.16 Cohesion versus Volumetric Block Proportion

Lindquist, 1994

Scott Dam melange strength testing results



Prof. R Goodman

8. Adjust the linear block proportion to account for uncertainty

Determination of volumetric block proportions

- Application of stereological principle:

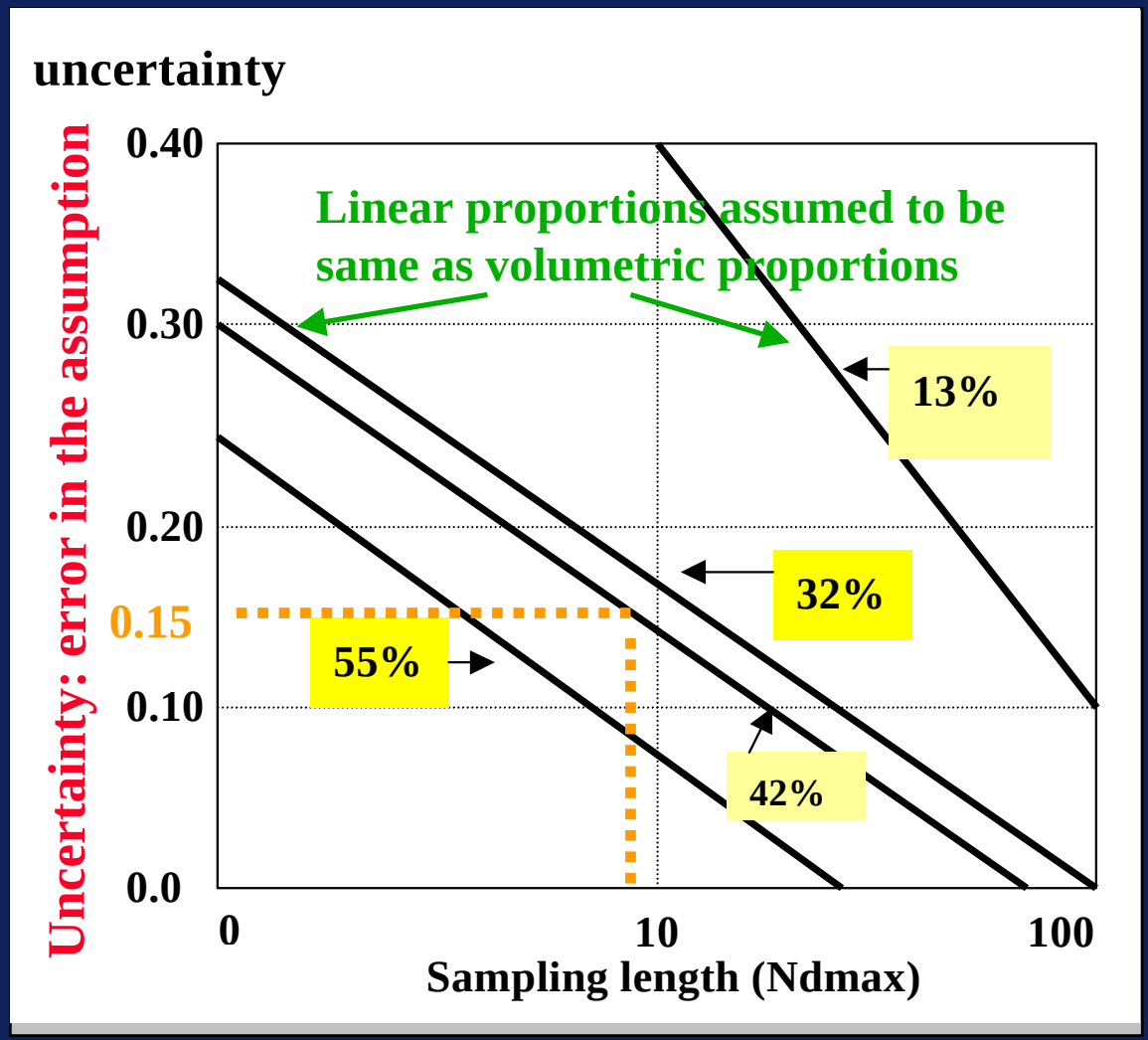
linear proportion = volumetric proportion

Determine linear proportion from drill core

- Beware uncertainty!

Warnings!!!!

- So, although stereology says that volumetric % = linear %
  - It is TRUE ONLY when you have sufficient linear measurements!! (lots of $$$ drilling!!)

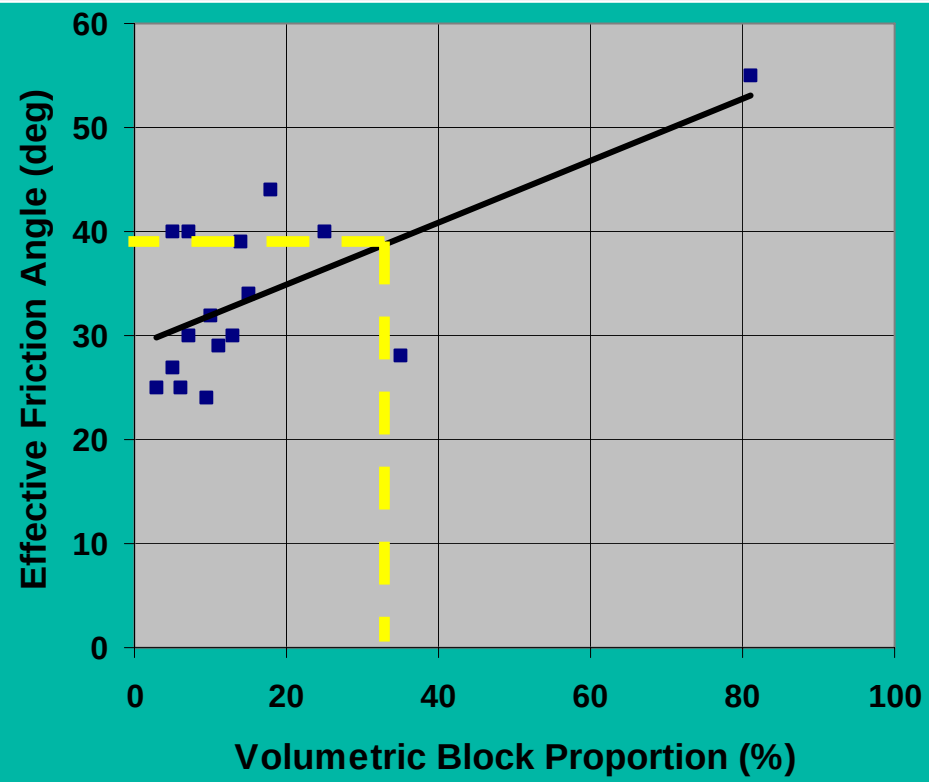


Estimated volumetric properties on the basis of Scott Dam linear boring measurements

0.15x40% = 6%: use 34% block proportion

9. Estimate overall bimrock strength

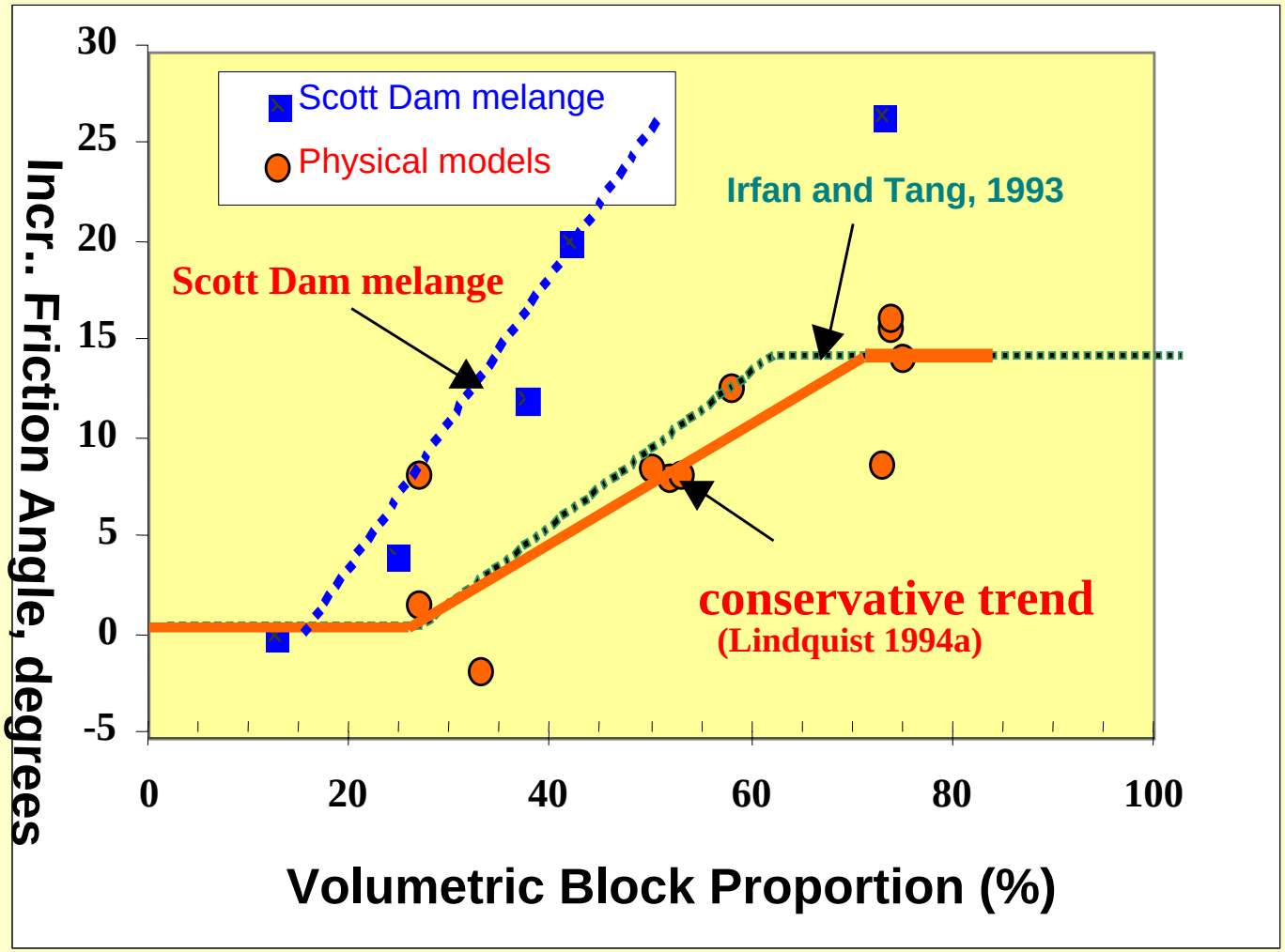
Strength of Franciscan below Scott Dam



Approx 39% friction for 34% volumetric block proportion

Medley, 2002; after Goodman and Ahlgren, 2001

Strength of bimrock depends on volumetric block proportion



Strength and deformation properties of Melange Bimrocks

- Strength and deformation of melanges are independent of block strengths (Lindquist and Goodman,1994)
- Overall strength is directly related to volumetric block proportion
- Blocks adds friction, stiffen the mixture and reduce cohesion.
- Must perform geotech tests with blocks in specimens

For more information, see contents of the CDROM

- **Characterizing melanges**

  Medley, 1998 (IAEG, Vancouver)

  Medley, 1998 (ASCE ISC, Atlanta)

  Medley, 1999, 2001 (Feldsbau, Austrian J. Geomechanics)

  Medley, 2002 (Eng. Geol. Practice No. Cal.)

- **Block size distributions in melanges**

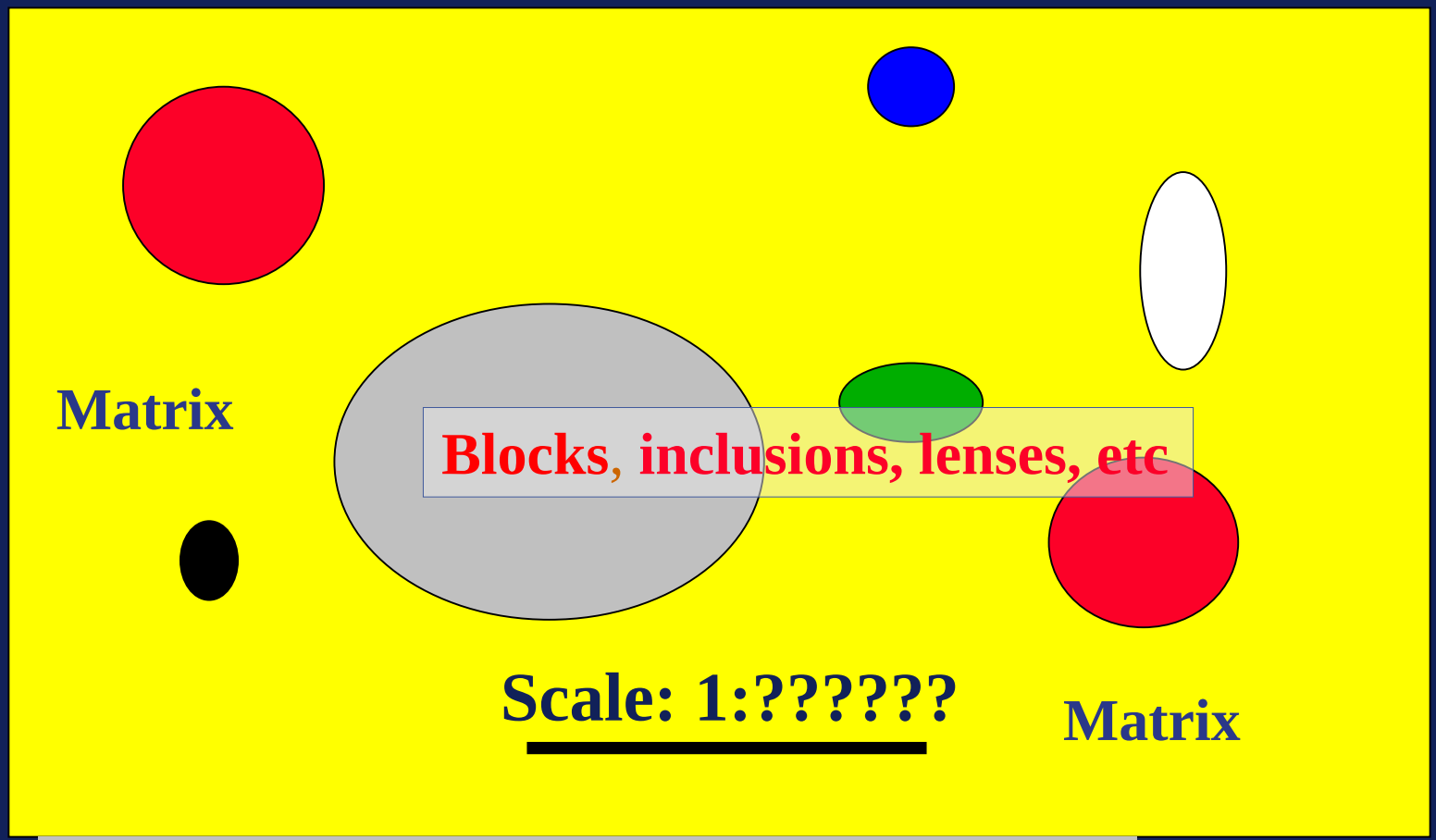
  Medley and Lindquist, 1995 (35th USRMC, Tahoe)

  Medley 2002 (NARMS Toronto)

- **Uncertainties from boring data in melanges**

  Medley, 1997 (IAEG, Athens)

BIG CONCLUSION 1:
Remember this picture!!!



Actual Distribution of Blocks

BIG CONCLUSION 2:
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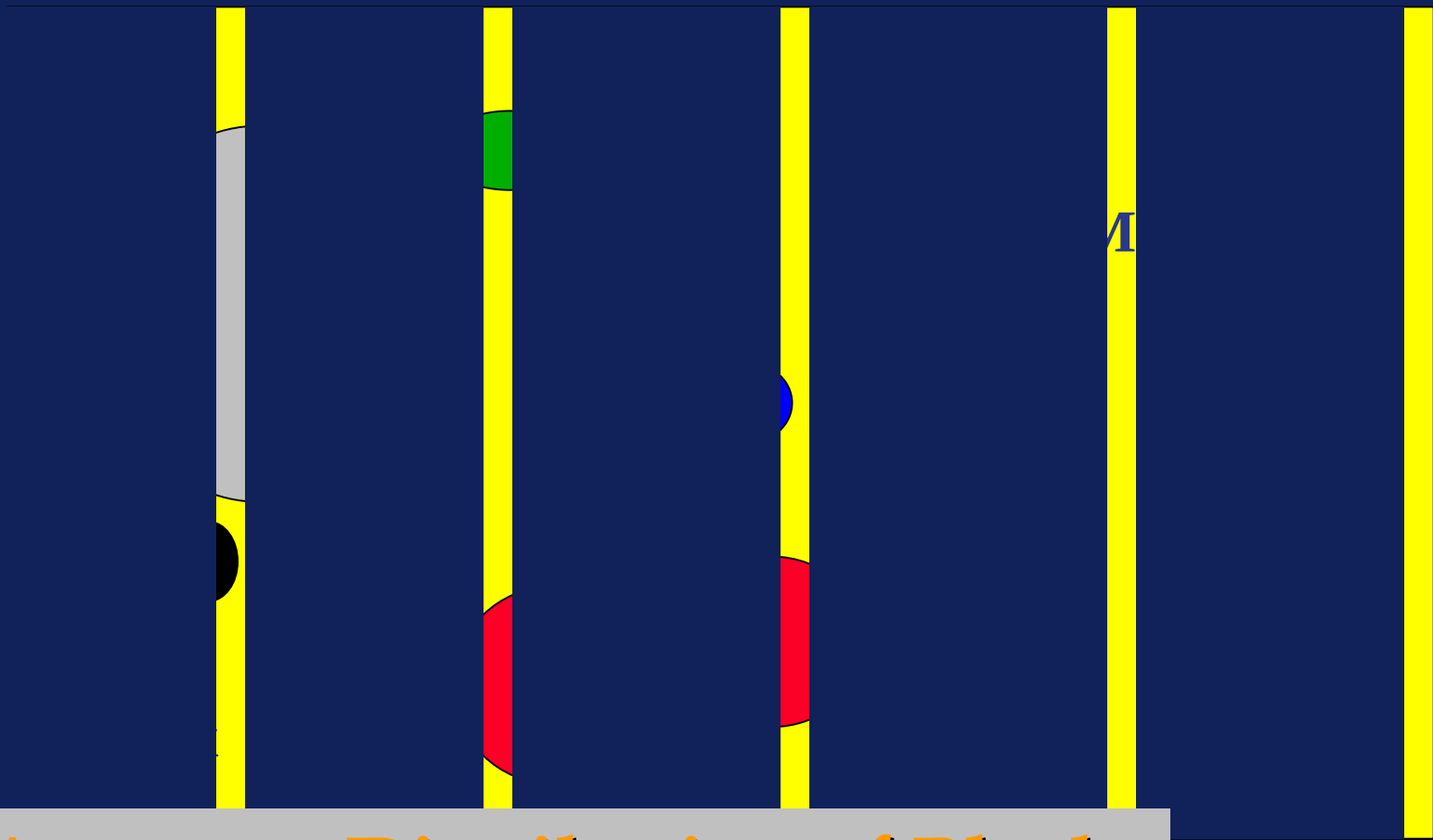

Apparent Distribution of Blocks

Willis, 2000

Conclusions continued:

- Bimrocks are NOT:
  - "soil with boulders",
  - "interlayered shale and sandstone"
  - "miscellaneous soils"
- Block volumes, sizes and lithologies are $important$ to Contractors/Owners and some effort should be made to determine them
- Block sizes should be estimated very conservatively for construction

Other CONCLUSIONS

- Melange bimrocks and other bimrocks mixtures are chaotic but can be characterized in a disciplined fashion
- Strength and deformation properties of bimrocks are determinable
- Uncertainties in estimates must be considered

THANK YOU FOR LISTENING TO ME FOR SO MANY HOURS!!!!